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COGENERATION TECHNOLOGY

ALTERNATIVES STUDY (CTAS)

GENERAL ELECTRIC COMPANY
FINAL REPORT

VOLUME III - INDUSTRIAL PROCESSES

W.B. Palmer, H.E. Gerlaugh
and R.R. Priestley
April 1980

PREPARED FOR

National Aeronautics Space Administration
Lewis Research Center
Under Contract DEN3-31

FOR

U.S. Department of Energy
Office of Energy Technology
Divison of Fossil Fuel Utilization

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FOREWORD

The Cogeneration Technology Alternatives Study (CTAS) was performed by the National Aeronautics and Space Administration, Lewis Research Center, for the Department of Energy, Division of Fossil Fuel Utilization. CTAS was aimed at providing information which will assist the Department of Energy in establishing research and development funding priorities and emphasis in the area of advanced energy conversion system technology for advanced industrial cogeneration applications. CTAS included two Department of Energy-sponsored/NASA-contracted studies conducted in parallel by industrial teams along with analyses and evaluations by the National Aeronautics and Space Administration's Lewis Research Center.

This document describes the work conducted by the Energy Technology Operation of the General Electric Company under National Aeronautics and Space Administration contract DEN3-31.

The General Electric Company contractor report for the CTAS study is contained in six volumes:

Cogeneration Technology Alternatives Study (CTAS), General Electric Company Final Report

Title	DOE Number	NASA Contract Report No.
GE Vol. 1 - Summary Report	DOE/NASA/0031-80/1	CR-159765
Vol. 2 - Analytic Approach	DOE/NASA/0031-80/2	CR-159766
Vol. 3 - Industrial Process Characteristics	DOE/NASA-0031-80/3	CR-159767
Vol. 4 - Energy Conversion System Characteristics	DOE/NASA-0031-80/4	CR-159768
Vol. 5 - Cogeneration System Results	DOE/NASA-0031-80/5	CR-159769
Vol. 6 - Computer Data	DOE/NASA-0031-80/6	CR-159770

Members of the technical staffs of the following organizations have developed and provided information for the General Electric Company Cogeneration Technology Alternatives Study. The contributions of these people in time, effort, and knowledge are gratefully appreciated.

General Electric Company

- Corporate Research and Development
- Energy Systems Programs Department
- Energy Technology Operation
- Gas Turbine Division
- Industrial and Marine Steam Turbine Division
- Industrial Turbine Sales and Engineering Operation
- Installation and Service Engineering Business Division
- Space Division
- TEMPO
- Lamp Components Division

DeLaval

Dow Chemical

General Energy Associates

Institute of Gas Technology

J.E. Sirrine

Kaiser Engineers

N.A. Philips

This General Electric Company contractor report is one of a set of reports describing CTAS results. The other reports are the following:

Cogeneration Technology Alternatives Study (CTAS), Vol. I, Summary Report, NASA TM-81400.

Cogeneration Technology Alternatives Study (CTAS), Vol. II, Comparison and Evaluation of Results, NASA TM-81401

Cogeneration Technology Alternatives Study (CTAS) - United Technologies Corporation Final Report

Title	DOE Number	NASA Contract Report No.
UTC Vol. 1 - Summary	DOE/NASA/0030-80/1	CR-159759
Vol. 2 - Industrial Process Characteristics	DOE/NASA-0030-80/2	CR-159760
Vol. 3 - Energy Conversion System Characteristics	DOE/NASA-0030-80/3	CR-159761
Vol. 4 - Heat Sources, Balance of Plant and Auxiliary Systems	DOE/NASA-0030-80/4	CR-159762
Vol. 5 - Analytic Approach & Results	DOE/NASA-0030-80/5	CR-159763
Vol. 6 - Computer Data	DOE/NASA-0030-80/6	CR-159764

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Section 1

SUMMARY

Cogeneration systems in industry simultaneously generate electric power and thermal energy. Conventional nocogeneration installations use separate boilers or furnaces to produce the required thermal energy and purchase electric power from a utility which rejects heat to the outside environment. Cogeneration systems offer significant savings in fuel but their wide spread implementation by industry has been generally limited by economics and institutional and regulatory factors. Because of potential savings to the nation, the Department of Energy, Office of Energy Technology sponsored the Cogeneration Technology Alternatives Study (CTAS). The National Aeronautics & Space Administration, Lewis Research Center, conducted CTAS for the Department of Energy with the support of Jet Propulsion Laboratory and study contracts with the General Electric Company and the United Technologies Corporation.

OBJECTIVES

The objective of the CTAS is to determine if advanced technology cogeneration systems have significant payoff over current cogeneration systems which could result in more widespread implementation in industry and to determine which advanced cogeneration technologies warrant major research and development efforts.

Specifically, the objectives of CTAS are:

1. Identify and evaluate the most attractive advanced energy conversion systems for implementation in industrial cogeneration systems for the 1985-2000 time period which permit use of coal and coal-derived fuels.

2. Quantify and assess the advantages of using advanced technology systems in industrial cogeneration.

SCOPE

The following nine energy conversion system (ECS) types were evaluated in CTAS:

1. Steam turbine
2. Diesel engines
3. Open-cycle gas turbines
4. Combined gas turbine/steam turbine cycles
5. Stirling engines
6. Closed-cycle gas turbines
7. Phosphoric acid fuel cells
8. Molten carbonate fuel cells
9. Thermionics

In the advanced technology systems variations in temperature, pressure ratio, heat exchanger effectiveness and other changes to a basic cycle were made to determine desirable parameters for many of the advanced systems. Since coal and coal-derived fuels were emphasized, atmospheric and pressurized fluid bed and integrated gasifiers were evaluated.

For comparison, currently available non-condensing steam turbines with coal-fired boilers and flue gas desulfurization, gas turbines with heat recovery steam generators burning residual and distillate petroleum fuel and medium speed diesels burning petroleum distillate fuel were used as a basis of comparison with the advanced technologies.

In selecting the cogeneration energy conversion system configurations to be evaluated, primary emphasis was placed on system concepts fired by coal and coal-derived fuels. Economic evaluations were based on industrial ownership of the cogeneration system. Solutions to institutional and regulatory problems which impact the use of cogeneration were not addressed in this study.

Over fifty industrial processes and a similar number of state-of-the-art and advanced technology cogeneration systems were matched by

General Electric to evaluate their comparative performance. The industrial processes were selected as potentially suited to cogeneration primarily from the six largest energy consuming sectors in the nation. Advanced and current technology cogeneration energy conversion systems, which could be made commercially available in the 1985 to 2000 year time frame, were defined on a consistent basis. These processes and systems were matched to determine their effectiveness in reducing fuel requirements, saving petroleum, cutting the annual costs of supplying energy, reducing emissions, and improving the industry's return on investment.

Detailed data were gathered on 80 process plants with major emphasis on the following industry sectors:

1. SIC20 - Food and Kindred Products
2. SIC26 - Pulp and Paper Products
3. SIC28 - Chemicals
4. SIC29 - Petroleum Refineries
5. SIC32 - Stone, Clay and Glass
6. SIC33 - Primary Metals

In addition, four processes were selected from SIC22 - Textile Mill Products and SIC24 - Lumber and Wood Products. The industry data includes current fuel types, peak and average process temperature and heat requirements, plant operation in hours per year, waste fuel availability, electric power requirements, projected growth rates to the year 2000, and other factors needed in evaluating cogeneration systems. From this data approximately fifty plants were selected on the basis of: energy consumption, suitability for cogeneration, availability of data, diversity of types such as temperatures, load factors, etc., and range of ratio of process power over process heat requirements.

Based on the industrial process requirements and the ECS characteristics, the performance and capital cost of each cogeneration system and its annual cost, including fuel and operating costs, were compared with nocogeneration systems as currently used. The ECS was either sized to

match the process heat requirements (heat match) and electricity either bought or sold or sized to match the electric power (power match) in which case an auxiliary boiler is usually required to supply the remaining heat needs. Cases where there was excess heat when matching the power were excluded from the study. With the fuel variations studied there are 51 ECS/fuel combinations and over 50 processes to be potentially matched in both heat and power resulting in a total of approximately 5000 matches calculated. Some matches were excluded for various reasons; e.g., the ECS out of temperature range or excess heat produced, resulting in approximately 3100 matches carried through the economic evaluation. Results from these matches were extrapolated to the national level to provide additional perspective on the comparison of advanced systems.

RESULTS

A comparison of the results for these specific matches lead to the following observations on the various conversion technologies:

1. The atmospheric and pressurized fluidized bed steam turbine systems give payoff compared to conventional boiler with flue gas desulfurization-steam turbine systems which already appear attractive in low and medium power over heat ratio industrial processes.

2. Open-cycle gas turbine and combined gas turbine/steam turbine systems are well suited to medium and high power over heat ratio industrial processes based on the fuel prices used in CTAS. Regenerative and steam injected gas turbines do not appear to have as much potential as the above systems, based on GE results. Solving low grade coal-derived fuel and NO_x emission problems should be emphasized. There is payoff in these advanced systems for increasing firing temperature.

3. The closed-cycle gas turbine systems studied by GE have higher capital cost and poorer performance than the more promising technologies.

4. Combined-cycle molten carbonate fuel cell and gas turbine/steam turbine cycles using integrated gasifier, and heat matched to medium and high power over heat ratio industrial processes and exporting surplus power to the utility give high fuel savings. Because of their high capital cost, these systems may be more suited to utility or joint utility-industry ownership.

5. Distillate-fired fuel cells did not appear attractive because of their poor economics due to the low effectiveness of the cycle configurations studied by GE and the higher price of distillate fuel.

6. The very high power over heat ratio and moderate fuel effectiveness characteristics of diesel engines limit their industrial cogeneration applications. Development of an open cycle heat pump to increase use of jacket water for additional process heat would increase their range of potential applications.

To determine the effect of the national fuel consumption and growth rates of the various industrial processes together with their distribution of power to heat ratios, process steam temperatures and load factors, each energy conversion system was assumed implemented without competition and its national fuel, emissions, and cost of energy estimated. In this calculation it was assumed that the total savings possible were due to implementing the cogeneration systems in new plants added because of needed growth in capacity or to replace old, unserviceable process boilers in the period from 1985 to 1990. Also, only those cogeneration systems giving an energy cost savings compared with nocogeneration were included in estimating the national savings. Observations on these results are:

1. There are significant fuel, emissions, and energy cost savings realized by pursuing development of some of the advanced technologies.

2. The greatest payoff when both fuel energy savings and economics are considered lies in the steam turbine systems using atmospheric and pressurized fluidized beds. In a comparison of the national fuel and energy cost savings for heat matched cases, the atmospheric fluidized bed showed an 11% increase in fuel saved and 60% additional savings in levelized annual energy cost savings over steam turbine systems using conventional boilers with flue gas desulfurization whose fuel savings would be, if implemented, 0.84 quads/year and cost savings $1.9 billion/year. The same comparison for the pressurized fluidized bed showed a 73% increase in fuel savings and a 29% increase in energy cost savings.

3. Open-cycle gas turbines and combined-cycles have less wide application but offer significant savings. The advanced residual-fired open-cycle gas turbine with heat recovery steam generator and firing temperature of 2200 F were estimated to have a potential national saving of 39% fuel and 27% energy cost compared to currently available residual-fired gas turbines whose fuel savings would be, if implemented, 0.18 quads/year and cost savings $0.33 billions/year.

4. Fuel and energy cost savings are several times higher when the cogeneration systems are heat matched and surplus power exported to the utility than when the systems are power matched.

Other important observations made during the course of performing CTAS were:

1. Comparison of the cogeneration systems which are heat matched and usually exporting power to the utility with the power matched systems shows the systems exporting power have a much higher energy savings, often reaching two to five times the power match cases. In the past, with few exceptions, cogeneration systems have been matched to the industrial process so as not to export power because of numerous load management, reliability, regulatory, economic and institutional reasons. A concerted effort is now underway by a number of government agencies, industries, and utilities to overcome these impediments and it should be encouraged if the nation is to receive the full potential of industrial cogeneration.

2. The economics of industrially owned cogeneration plants are very sensitive to fuel and electric power costs or revenues. Increased price differentials between liquid fuels and coal would make integrated gasifier fuel cell or combined-cycle systems attractive for high power over heat industrial processes.

3. Almost 75% of the fuel consumed by industrial processes studied in CTAS, which are representative of the national industrial distribution, have power over heat ratios less than 0.25. As a result energy conversion systems, such as the steam turbine using the atmospheric or pressurized fluidized bed, which exhibit good performance and economics when heat matched in the low power over heat ratio range, give the largest national savings.

Section 2

INTRODUCTION

BACKGROUND

Cogeneration is broadly defined as the simultaneous production of electricity or shaft power and useful thermal energy. Industrial cogeneration in the context of this study refers specifically to the simultaneous production of electricity and process steam or hot water at an individual industrial plant site. A number of studies addressing various aspects of cogeneration as applied to industry have been made in the last few years. Most of these focused on the potential benefits of the cogeneration concept. CTAS, however, was concerned exclusively with providing technical, cost, and economic comparisons of advanced technology systems with each other and with currently available technologies as applied to industrial processes rather than the merits of the concept of cogeneration.

While recognizing that institutional and regulatory factors strongly impact the feasibility of widespread implementation of cogeneration, the CTAS did not attempt to investigate, provide solutions, or limit the technologies evaluated because of these factors. For example, cogeneration systems which were matched to provide the required industrial process heat and export excess power to the utilities were evaluated (although this has usually not been the practice in the past) as well as systems matched to provide only the amount of power required by the process. Also, no attempt was made to modify the industrial processes to make them more suitable for cogeneration. The processes were defined to be representative of practices to be employed in the 1985 to 2000 time frame.

The cogeneration concept has been applied in a limited fashion to power plants since the turn of the century. Their principal advantage is that they offer a significant saving in fuel over the conventional method of supplying the energy requirements of an industrial plant by purchasing power from the utility and obtaining steam from an on-site process boiler.

The saving in fuel by a cogeneraiton system can be seen by taking a simple example of an industrial process requiring 20 units of power and 100 units of process steam energy. A steam turbine cogeneration system (assuming it is perfectly matched, which is rarely the case) can provide these energy needs with fuel effectiveness or power plus heat over input fuel ratio of 0.85 resulting in a fuel input of 141 units. In the conventional nocogeneration system the utility with an efficiency of 33% requires 60 units of fuel to produce the 20 units of power and the process boiler with an efficiency of 85% requires 118 units of fuel to produce the required steam making a total fuel required of 178 units. Thus the cogeneration system has a fuel saved ratio of 37 over 178 or 21%.

In spite of this advantage of saving significant amounts of fuel, the percentage of industrial power generated by cogeneration, rather than being purchased from a utility, has steadily dropped until it is now less than 5% of the total industrial power consumed. Why has this happened? The answer is primarily one of economics. The utilities with their mix in ages and capital cost of plants, relative low cost of fuel, steadily improving efficiency and increasing size of power plants all made it possible to offer industrial power at rates more attractive than industry could produce it themselves in new cogeneration plants.

Now with long term prospects of fuel prices increasing more rapidly than capital costs, the increased use of waste fuels by industry and the need to conserve scarce fuels, the fuel savings advantage of cogenerating will lead to its wider implementation. The CTAS was sponsored by the US Department of Energy to obtain the input needed to establish R&D funding priorities for advanced energy conversion systems which could be used in industrial cogeneration applications. Many issues, technical, institutional

and regulatory, need to be addressed if industrial cogeneration is to realize its full potential benefits to the nation. However, the CTAS concentrated on one portion of these issues, namely, to determine from a technical and economic standpoint the payoff of advanced technologies compared to currently available equipments in increasing the implementation of cogeneration by industry.

OBJECTIVE, OVERALL SCOPE, AND METHODOLOGY

The objectives of the CTAS effort were to:

1. Identify and evaluate the most attractive advanced conversion systems for implementation in industrial cogeneration systems for the 1985-2000 time period which permit increased use of coal or coal-derived fuels.

2. Quantify and assess the advantages of using advanced technology systems in industrial cogeneration.

To select the most attractive advanced cogeneration energy conversion systems incorporating the nine technologies to be studied in the CTAS, a large number of configurations and cycle variations were identified and screened for detail study. The systems selected showed desirable cogeneration characteristics and the capability of being developed for commercialization in the 1985 to 2000 year time frame. The advanced energy conversion system-fuel combinations selected for study are shown in Table 2-1 and the currently available systems used as a basis of comparison are shown in Table 2-2. These energy conversion systems were then heat matched and power matched to over 50 specific industrial processes selected primarily from the six major energy consuming industrial sectors of food; paper and pulp; chemicals; petroleum refineries; stone, clay and glass; and primary metals. Several processes were also included from wood products and textiles.

On each of these matches analyses were performed to evaluate and compare the advanced technology systems on such factors as:

- Fuel Energy Saved
- Flexibility in Fuel Use

Table 2-1

GE-CTAS ADVANCED TECHNOLOGY COGENERATION ENERGY CONVERSION SYSTEMS MATCHED TO FUELS

	Coal	Coal Derived Liquids Residual	Coal Derived Liquids Distillate
Steam Turbine	AFB*	Yes	---
Pressurized Fluid Bed	Yes	---	---
Gas Turbine			
Open Cycle-HRSG	---	Yes	Yes
Regenerative	---	---	Yes
Steam Injected	---	Yes	---
Combined Gas Turbine/Steam Turbine Cycle			
Liquid Fired	---	Yes	---
Integrated Gasifier Combined Cycle	Yes	---	---
Closed Cycle-Helium Gas Turbine	AFB	---	---
Thermionic			
HRSG	FGD*	Yes	---
Steam Turbine Bottomed	FGD	Yes	---
Stirling	FGD	Yes	Yes
Diesels			
Medium Speed	---	Yes	Yes
Heat Pump	---	Yes	Yes
Phosphoric Acid Fuel Cell Reformer	---	---	Yes
Molten Carbonate Fuel Cell			
Reformer	---	---	Yes
Integrated Gasifier			
HRSG	Yes	---	---
Steam Turbine Bottoming	Yes	---	---

* AFB - Atmospheric Fluidized Bed
FGD - Flue Gas Desulfurization

Table 2-2

GE-CTAS STATE OF ART COGENERATION ENERGY CONVERSION MATCHED TO FUELS

	Coal	Petroleum Derived Residual	Petroleum Derived Distillate
Steam Turbine	FGD	Yes	---
Gas Turbine	---	Yes	Yes
Diesel	---	Yes	Yes

- Capital Costs
- Return on Investment and Annual Energy Cost Saved
- Emissions
- Applicability to a Number of Industries.

These matches were evaluated, both on a specific process site basis, and on a national level where it was assumed that each ECS is applied without competition nationwide to all new applicable industrial plants.

Because of the many different types of conversion systems studied and myriad of possible combinations of conversion system and process options, key features of the study were:

- The use of consistent and simplified but realistic characterizations of cogeneration systems
- Use of the computer to match the systems and evaluate the characteristics of the matches.

A major effort was made to strive for consistency in the performance, capital cost, emissions, and installation requirements of the many advanced cogeneration energy conversion systems. This was accomplished first by NASA-LeRC establishing a uniform set of study groundrules for selection and characterization of the ECS's and industrial processes, calculation of fuel and emissions saved and analysis of economic parameters such as levelized annual energy cost and return on investment. These groundrules and assumptions are described in Section 3. Second, in organizing the study, as shown in Figure 2-1, GE made a small group called Cogeneration Systems Technology responsible for establishing the configuration of all the ECS's and obtaining consistent performance, cost and emission characteristics for the advanced components from the GE organizations or subcontractors developing these components. This team, using a standard set of models for the remaining subsystems or components, then prepared the performance, capital costs, and other characteristics of the overall ECS's. As a result, any component or subsystem, such as fuel storage and handling, heat recovery steam generator or steam turbine, appearing in

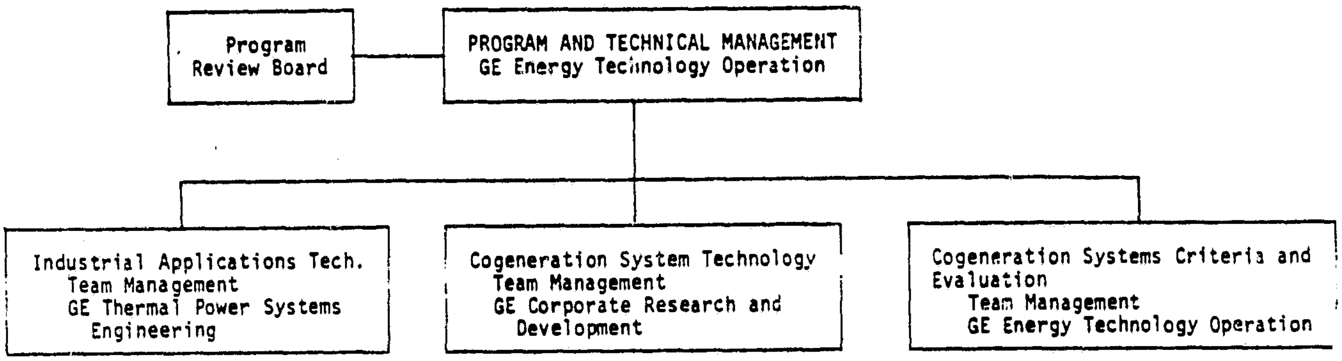

Figure 2-1. GE-CTAS Project Organization

more than one type ECS is based on the same model. This method reduces the area of possible inconsistency to the advanced component which, in many ECS's, is a small fraction of the total system. The characterization of the ECS's is described in Sections 5 and 6. The functions of obtaining consistent data on industrial processes from the industrial A&E subcontractors was the responsibility of the Industrial Applications Technology group and is described in Section 4. Matching of the ECS's and processes and making the overall performance and economic evaluations and comparisons was the responsibility of Cogeneration Systems Criteria and Evaluation. The methodology of matching the cogeneration systems is detailed in Section 8, the results of the performance analysis in Section 9, economic analysis in Section 10, the national savings in Section 11, and overall results and observations in Section 12.

Section 5

INDUSTRIAL PROCESSES

5.1 SELECTION PROCESS

Industrial processes were selected to provide a realistic framework to be used in the evaluation of cogeneration systems. One of the criteria used in the selection was energy consumption. The 2-digit SIC industries were reviewed and selected for their total energy consumption. Within each 2-digit sector specific industries (4-digit SIC) were selected based on additional criteria, principally the expected growth of the industry in the next 20-25 years.

The major energy consuming sectors classified in the United States Office of Management and Budget, Manufacturing Division of Standard Industrial Classification (SIC) Manual have energy usage reported in the Annual Survey of Manufacturers for 1976 given in Table 5.1-1.

The energy consumption of these industries as measured by the 1976 Annual Survey of Manufacturers data is 84.9% of total national industrial consumption. These data are only for purchased fuel and electric energy and do not take into account the use of captive energy sources or the electric utility conversion efficiency of fuel energy to electric energy.

Since the emphasis was placed on selecting processes from the major energy consuming industrial groups, subcontractors with expertise in industrial processes in these fields were retained to provide necessary process information.

Table 5.1-1

NATIONAL INDUSTRY USE OF ENERGY
(1976)

SIC	Industry	Purchased Power & Electric Energy Btu x 10^{12}	% National Energy
20	Food & Kindred Products	937.5	7.4
22	Textile	328.6	2.6
24	Lumber	243.8	1.9
26	Paper & Allied Products	1 294.6	10.3
28	Chemical & Allied Products	3 017.1	23.9
29	Petroleum & Coal Products	1 291.7	10.2
32	Stone, Clay & Glass Products	1 219.6	9.7
33	Primary Metals Industries	2 380.5	18.9
	Total	10 713.4	84.9
	All Industries	12 625.3	100.0

The subcontractors are listed in Table 5.1-2.

Table 5.1-2

SUBCONTRACTORS FOR INDUSTRIAL PROCESS DATA

SIC	Industry	Subcontractor
20	Food & Kindred Products	General Energy Associates
22	Textile	J.E. Sirrine Co.
24	Lumber	J.E. Sirrine Co.
26	Paper & Allied Products	J.E. Sirrine Co.
28	Chemical & Allied Products	Dow Chemical, Midland
29	Petroleum & Coal Products	Dow Chemical, Midland
32	Glass	GE Lamp Glass
32	Stone & Clay	Kaiser Engineers
33	Primary Metals Industries	Kaiser Engineers

To select processes within these industries the industrial process subcontractors were instructed to gather energy use growth trends for the top energy consuming industrial plants within their assigned industrial groups.

Following are some of the criteria used for selecting processes within each 2-digit sector. Processes selected must:

- represent processes anticipated to be used in the 1985-2000 time frame
- represent major energy consuming industries
- be potentially good candidates for cogeneration
- have sufficient data available for analysis
- include diverse characteristics requiring a variety of power systems
- cover a variety of fuel types with emphasis on processes requiring clean fuels in the 1985-2000 time period.

Initially in the process selection the meaning of "process" was an industrial plant which had one principal process and product output. In the chemical industry, plants are highly integrated with a large mix of processes and products. Heat and electric power requirements vary widely and depend on the product mix. But, it is anticipated that no new green field chemical plants will be constructed in the 1985-2000 time period and that additions to capacity will be accomplished through plant expansions at existing sites. It appeared reasonable to consider cogeneration as applied to separate processes because chemical plant capacity additions could be made on a process basis. In addition, requirements were estimated for the central power station for an integrated chemical plant.

In the petroleum refining industry there are many different crude oils processed in the U.S. Any refinery may process one or many of the crudes - as blends or separately. Each crude has different distillation properties and sometimes require different processes to produce distillation properties and sometimes require different processes to produce the same end products. Types of crudes used in refineries vary as do the products produced and it is therefore difficult to describe a typical refinery. Also, as in the chemical industry, increased capacity will be accomplished through plant expansion. It was decided that refineries can be adequately represented for purposes of this study be modeling three different sizes, each with a mix of representative processes.

Typical plant capacities for each industry have been selected where appropriate to represent sizes of new plants expected to be constructed in the 1985-2000 time period. In some instances, plants employing the same process but having different capacities were selected because it is anticipated that cogeneration economics will be a function of required energy conversion system size.

Plants were also selected from the Textile and Lumber products area. Processes in the textile industry have a high steam use and the lumber industry shows potential for a high growth rate.

A list of the final industries selected for further anlaysis is given in Table 5.1-3.

More details of the selection process and the data used in the selection is given in the subcontractor reports contained in Appendix A.

Table 5.1-3

SELECTED INDUSTRY PROCESSES & SUMMARY OF ENERGY REQUIREMENTS

SIC Code	Process No.	Description	Process Electric Power MW_e	Process Electric Power MBtu/hr	Process Steam MBtu/hr	% Hot Water	Temperature °F Peak	Temperature °F Avg.	Power /Heat Ratio	Load Factor hrs/yr	Primary Fuel	By-Product or Waste Fuel Avail MBtu/hr	National Energy Consumption Utility + Site 10^{12} Btu/yr 1976	1985	2000
20 FOOD AND KINDRED PRODUCTS (a)															
2011	1	Meat-Packing	1.940	6.625	24	40	250	250	0.28	2100	Gas		71	96	168
2026	1	Fluid Milk	1.310	4.474	11	50	250	250	0.41	2100	Gas		71	80	101
2046	1	Wet Corn Milling	28.500	97.327	659		250	250	0.15	6600	Gas		104	141	159
2063	1	Beet Sugar Refining	4.700	16.050	301		250	250	0.05	2800	Gas	76.47	100	118	162
2082	1	Malt Beverage	6.040	20.627	86	60	250	250	0.24	6600	Gas		75	120	190
22 TEXTILE MILL PRODUCTS (b)															
2260	1	Textile Finishing	6.200	21.[illegible]73	[illegible]58		341	331	0.13	6240	Coal		75	75	75
24 LUMBER AND WOOD PRODUCTS (c)															
2421	1	Soft Wood-Lumber Sawmill	1.500	5.123	30		353	353	0.17	4000	Bark-Sawdust	41.2	237	300	400
2436	1	Soft Wood-Plywood/Veneer	3.000	10.245	75		406	406	0.14	6000	Bark	100.0	100	150	275
2492	1	Particle Board	5.000	17.075	37		406	406	0.46	8000	Natural Gas	41.2	32	100	172
26 PAPER & ALLIED PRODUCTS (d)															
2621	2	Bleached Kraft	50.000	170.750	780		366	340	0.22	8400	Coal	353	416	454	784
2621	4	Unbleached Kraft	29.000	99.035	610		366	328	0.16	8400	Coal	259	405	[illegible]	950
2621	6	Neutral Sulfide Semichemical	20.000	68.300	307		366	345	0.22	8400	Coal		63	69	128
2621	7	Thermo-Mechanical Pulping	31.300	106.889	183		366	355	0.58	8400	Coal		102	110	205
2621	8	Waste Paper	15.000	51.225	224		366	355	0.21	8400	Coal		176	191	419
28 CHEMICAL & ALLIED PRODUCTS (e)															
2800	1	Small Integrated Power Plant	32.500	110.923	1100			366	0.101	8760					
2800	2	Medium Integrated Power Plant	77.200	263.484	1054			366	0.25	8760					
2800	3	Large Integrated Power Plant	97.200	331.744	947			366	0.35	8760					
2812	1	Chlorine - Caustic Soda	120.000	409.800	265		338	311	1.55	8500	Any		180	240	300
2813	1	Cryogenic Oxygen	34.000	116.110	0		0	0	999.99	8400	Electric		22	33	66
2819	1	Alumina	30.290	103.440	980		495	434	0.11	8136	Coal-Oil		53	76	135
2821	2	Vinyl Chloride	4.000	13.660	207		422	373	0.07	8300	Gas		50	110	160
2821	3	Low Density Polyethylene Resin	55.000	187.825	16		448	448	11.74	7900	Any		18	38	60

Table 5.1-3 (Cont'd)

SELECTED INDUSTRY PROCESSES & SUMMARY OF ENERGY REQUIREMENTS

SIC Code	Process No.	Description	Process Electric Power MW_e	Process Electric Power MBtu/hr	Process Steam MBtu/hr	% Hot Water	Temperature °F Peak	Temperature °F Avg.	Power /Heat Ratio	Load Factor hrs/yr	Primary Fuel	By-Product or Waste Fuel Avail MBtu/hr	National Energy Consumption Utility + Site 10^{12} Btu/yr 1978	1985	2000
28 CHEMICAL & ALLIED PRODUCTS (Cont'd)															
2822	1	Styrene-Butadiene Rubber	7.500	25.612	35		338	338	0.73	7900	Any		7	9	13
2824	1	Polyester Fibre	32.000	109.280	30		406	406	3.64	7900	Gas-Oil		30	55	75
2824	2	Nylon Fibre	11.000	37.565	23		274	274	1.63	8760	Any		14	20	25
2865	2	Cumene-Benzene	0.600	2.049	0		0	0	999.99	8400	Gas-Oil		6.5	10	15
2865	3	Phenol/Acetone	6.000	20.490	300		489	398	0.07	8200	Any		20	45	60
2865	4	Ethylbenzene	0.700	2.390	220		489	489	0.01	7900	Oil-Gas		22	45	65
2869	1	Methanol Synthesis	1.500	5.123	133		574	538	0.04	7800	Feedstock	352.9	0	0	0
2869	4	Ethanol	3.300	11.270	400		460	460	0.03	7900	Gas-Oil	70.6	18	24	30
2873	1	Ammonia Synthesis	3.500	11.952	640		598	598	0.02	8400	Gas-Oil		200	250	305
2874	1	Phosphoric Acid	4.000	13.660	92		353	292	0.15	7900	Gas-Oil		35	48	60
2895	1	Carbon Black	4.000	13.660	20		298	298	0.68	7900	Oil-Gas		18	20	24
29 PETROLEUM REFINING (f)															
2911	1	Small Refinery	14.000	47.810	375		470	389	0.13	8760	Oil-Der		560	500	630
2911	2	Medium Refinery	52.000	177.500	1333		470	395	0.13	8760	Oil-Der		850	870	950
2911	3	Large Refinery	126.000	430.290	3042		470	385	0.14	8760	Oil		1220	1250	1280
32 STONE, CLAY AND GLASS (g)															
3211	1	Flat-Glass	5.600	19.124	0		0	0	999.99	7500	Nat-Gas				
3221	1	Glass Containers	5.100	17.416	0		0	0	999.99	7500	Nat-Gas				
3229	1	Press-Blown Glass	1.100	3.756	0		0	0	999.99	7500	Nat-Gas				
3241	1	Cement	20.316	69.379	0		0	0	999.99	7920	Coal				
33 PRIMARY METALS (h)															
3312	1	Specialty Steel	60.000	204.900	93		448	446	2.20	6700	Nat-Gas		560	643	835
3325	1	Integrated Steel	280.000	956.200	912		448	445	1.05	8400	Cok-Coal	529.4	3080	3539	4596
3325	4	Mini-Steel	40.000	136.600	91		448	446	1.50	6700	Nat-Gas		360	612	1070
3331	1	Copper-Fire Smelted	24.800	84.692	0		0	0	999.99	8400	Oil		4.6	5.8	9.3
3331	4	CopperAnode Smelted	10.100	34.491	40		364	364	0.86	7620	Oil		12.2	15.5	24.8
3334	1	Aluminum	756.000	2581.740	0		0	0	999.99	8760	Oil		31.8	49.2	86.4

5.2 DATA SUMMARY

The blank process data sheet indicating the data sought for each industrial process, is shown in Table 5.2-1. The completed data sheet, as supplied by the subcontractors for the selected industries, are included in their reports contained in Appendix A.

The data for each of the selected industries is summarized in Table 5.1-3(a) to (h). The electric power requirements are given in both MW of electricity and converted to the heat equivalent, MBtu/hr. The process heat requirement indicates the quantity in MBtu/hr, the percent of the heat that is supplied as hot water when it is not all steam, and both peak and average temperature. The power to heat ratio, as implied, is the ratio of process power to heat in the same units. The load factor indicates the number of hours per year that the industry operates or requires heat and power. The primary fuel listed is that currently being used. In those industries where waste fuel is available the quantity in MBtu/hr is shown. The last three columns show the national energy consumption in 10^{12} Btu/yr for the year 1978 and that anticipated for the years 1985 to 2000. These data include fuel energy required or sensible (direct) heat required as well as for steam and generation of electric power.

Graphical summaries of this data are shown in Figures 5.2-1 to 5.2-3. In Figure 5.2-1 the power to heat ratio (P/H) is shown versus the total process heat. Diagonal lines indicate the electric power requirements in MW. The process heat requirements vary from 10 to over 3000 MBtu/hr or a factor of 300. Power to heat ratios vary from 0.01 to 3.6 on the figure but one process (low density polyurethane) is off the scale of the chart at nearly 12 (see Table 5.1-3(e)). Several industries have requirements for heat that are well above the range of temperatures applicable to the conversion systems being considered. These industries, like glass, cement, copper smelters, and aluminum are shown in Table 5.1-3 to have no process heat requirement; however, they could have the potential for use with bottoming conversion systems to produce electricity

because they have larger amounts of waste heat available at relatively high temperatures. Because of the severe operating conditions - e.g., high temperatures and corrosive gases - each would have to be considered separately.

Figure 5.2-2 shows P/H versus the process temperature. Except for the very high temperature industries all require temperatures in the 250 to 600 F range. Figure 5.2-3 shows P/H versus the load factor in hr/yr that the plant is operated. Most plants have a high load factor since the industries were selected on the basis of suitability for cogeneration and it was felt that a high usage rate would be required to cover the increased capital investment generally required for a cogeneration system. Several plants with low load factors were selected to determine whether or not cogeneration could be economic in such applications.

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Table 5.2-1

CTAS INDUSTRIAL PROCESS DATA SHEETS

A. Plant SIC/Name/Size: ______________________

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average ________kW; Peak ________kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
	@	,	,	
	@	,	,	
	@	,	,	

E. Other Heat to Process (Describe):

F. Plant Hours of Operation at Average Conditions: ____________hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description

Table 5.2-1 (Cont'd)

-2-

Plant SIC/Name/Size: ____________________

J. Fuels: Primary Fuel ________ / ________ mil. Btu/hr (HHV)
Secondary Fuel ________ / ________ mil. Btu/hr (HHV)
By-product Fuel ________ / ________ mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria: ____________________

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

Table 5.2-1 (Cont'd)

-3-

Plant SIC/Name/Size: ______________________________

R. Describe the level of capital investment in this industry. (1985-2000 time period)

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 ______________

In 2000 ______________

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might affect the energy conversion system requirements.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

W. National energy consumed by this process

In 1978 ______________

In 1985 ______________

In 2000 ______________

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

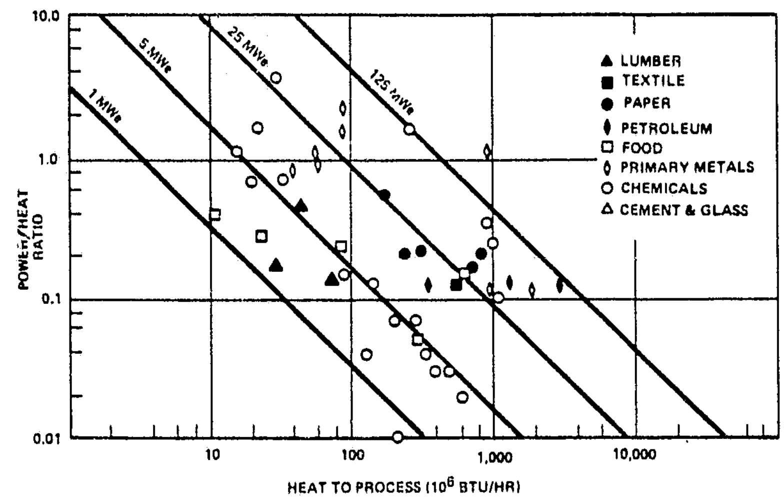


Figure 5.2-1. Industrial Process Characteristics Graphic Summaries (Power/Heat Ratio Versus Heat to Process)

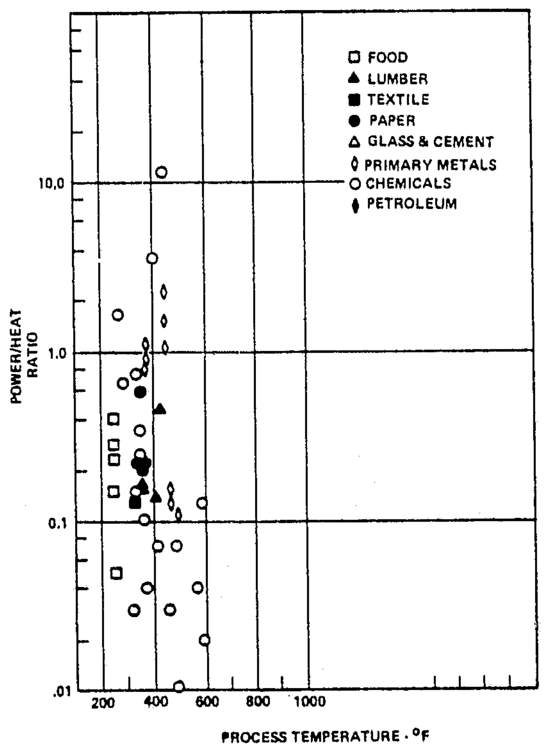


Figure 5.2-2 Industrial Process Characteristics Graphic Summaries (Power/Heat Ratio Versus Process Temperature)

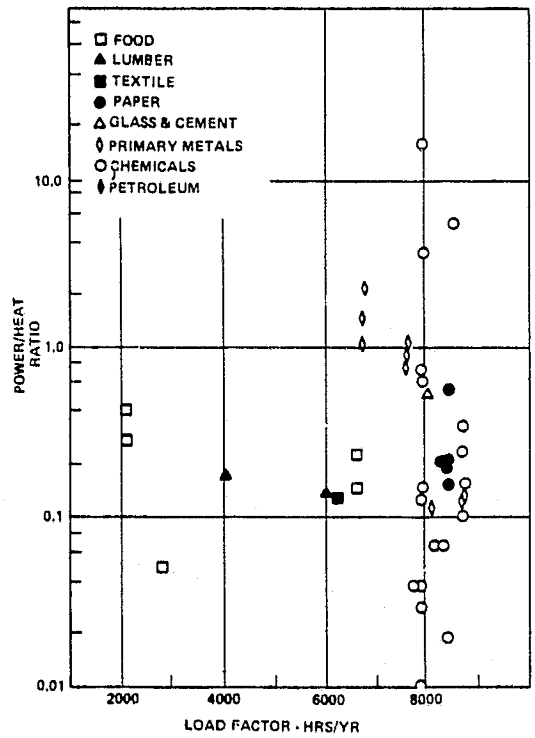


Figure 5.2-3. Industrial Process Characteristics Graphic Summaries (Power/Heat Ratio Versus Load Factor)

5.3 PROCESS DEFINITION AND DATA

Each subcontractor was requested to supply the completed data sheets, descriptions of the processes, flow diagrams, a discussion of current plants and future plans or trends, analysis of the energy requirements, and a selection with rationale of the processes to be used for studying the cogeneration energy conversion systems.

As should be expected with the wide variety of industries considered, not all subcontractors used the same approach or format in reporting the results. After the initial data was submitted and discrepancies or errors corrected, the data was immediately used in the Task 4 analysis. Because of the time limitation and the cost of making refinements, the subcontractors were not asked to produce a final report other than the draft copies which were submitted. These draft copies, without alterations, are included in Appendix A.

5.4 ESTIMATED NATIONAL PROJECTIONS

The data contained in the reports of Appendix A were analyzed and summarized to provide the data for making estimates of the potential saving on a national basis. This analysis was performed by General Energy Associates (GEA) and is contained in Appendix B. GEA has added comments to the data where their estimates disagree with the data sheets. These comments were later reflected in their methodology which they developed for the national projections.

GEA also provided a breakdown of the fuel use by type for each industry. This data is given in Table 5.4-1. Since GEA made these estimates independent of other industrial process subcontractors, the GEA values will often vary from those found in the subcontractor process data sheets.

The fuel distribution provided in Table 5.4-1 is for the national average for each of the 4-digit SIC industries. The information provided in the CTAS work sheets of Appendix A (Plant Data Sheets) represent the type fuel used for that specific plant or that process within the 4-digit sector. Where no breakdown is provided by the CTAS Plant Data Sheets, the national average may be used and the fuel type with the largest percentage should represent the primary fuel. In many cases the on-site fuel is used (e.g., bark and residual oil) and this should be considered since the Census numbers represent the purchased fuels.

The unit process waste streams within the indicated process that might be suitable for bottoming cycles were also estimated by GEA and are shown in Table 5.4-2. The energy content is calculated as follows:

$$Q = \dot{m}\, cp(T - T_{amb})$$

where

$$T_{amb} \sim 100^{o}F$$

and $$C_p \sim \frac{1}{4}$$

From this the mass flow may be estimated. The pound production can be multiplied by Energy Content (column 3 - Btu/lb) to obtain Btu and use with the above equation to get the mass flow.

Table 5.4-1

PERCENTAGE PURCHASED FOSSIL FUEL USE BY TYPE OF FUEL

	SIC	Coal	Oil	Gas	Other
A. SIC 20	2011	4	17	59	20
	2026	1	22	50	27
	2046	34	12	54	--
	2063	11	18	71	--
	2082	5	33	55	7
B. SIC 22	2260	18	40	30	12
C. SIC 24	2421	-	28	40	32
	2436	-	9	64	27
	2492	-	35	49	16
D. SIC 26	2621-2 2621-4 2621-6 2621-7 2621-8	19	47	30	4
E. SIC 28	2812	40	8	51	1
	2813	-	5	92	3
	2819	10	12	75	3
	2821-2 2821-3	20	20	49	11
	2822	33	3	37	22
	2824-1 2824-2	34	44	16	6
	2865-1 2865-2 2865-3 2865-4	5	23	69	3
	2869-1 2869-2 2869-3 2869-4	8	6	81	5
	2873	2	5	92	1
	2874	-	21	73	1
	2895	-	15	74	11
F. SIC 29	2911-1 2911-2 2911-3	-	18	90	2
G. SIC 32	3211	21	8	71	-
	3221	19	16	63	2
	3229	-	9	88	3
	3241-1 3241-2 3241-3 3241-4	57	9	34	-
H. SIC 33	3312-1 3312-2 3312-3	62	12	26	1
	3331-1 3331-2 3331-3 3331-4 3331-5 3331-6	57	9	33	1
	3334-1 3334-2 3334-3	55	4	39	2

Table 5.4-2

WASTE STREAMS FOR BOTTOMING CYCLES

SIC	Waste Source	Energy Content (Btu/lb product)	Temp. (°F)
3221	Melting Furnace	1000	1300
	Fining Furnace	320	1100
	Forehearth	570	1500
	Annealing	430	1200
3229	Melting Furnace	1000	1300
	Fining	690	1100
	Fire Polish	335	500
	Annealing	720	1200
	Drier	144	350
3241	Drier	200	725
	Kiln	460	1100
3312	Sintering	175	300
	Pelletizing	200	250
	Blast Stoves	80	700
	Blast Furnace	500	1000
	Electric Furnace	200	800
	Open Hearth	300	800
	BOF	100	2000
	Reheat Furnace	450	1200
	Reheat Furnace	450	1200
	Reheat Furnace	240	1200

5.5 APPENDIX A

1.0 The data contained in this appendix is that submitted by the industrial process subcontractors without revision or corrections. The responsibilities for the various sections of this appendix are listed below:

SECTION		DESCRIPTION	RESPONSIBILITY
2.0	- SIC 20 -	Food & Kindred Products	General Energy Associates
	2.1	General	
	2.2	Beet Sugar	
	2.3	Corn Wet Milling	
	2.4	Meat Packing	
	2.5	Malt Beverage	
	2.6	Fluid Milk	
3.0	- SIC 22 -	Textile Mill Products	J.E. Sirrine
	3.1	General	
	3.2	Weaving Mills, Manmade Fiber	
4.0	- SIC 24 -	Lumber and Wood Products	J.E. Sirrine
	4.1	General	
	4.2	Softwood, Veneer & Plywood	
5.0	- SIC 26 -	Paper & Allied Products	J.E. Sirring
	5.1	General	
	5.2	Integrated Paper Mills	
6.0	- SIC 28 -	Chemicals, Allied Products	Dow Chemical
	6.1	General	
	6.2	Light Olefins from Cracking Fuel Oils	
	6.2	Ammonia from Synthesis Gas	
	6.4	Carbon Black from Oil Pyrolysis	
	6.5	Methanol Synthesis	
	6.6	Polyester Fiber Synthesis	
	6.7	Oxygen/Nitrogen from Air	
	6.8	Cumene from Benzene Alkylation	
	6.9	Low Density Polyethylene Resin	

SECTION		DESCRIPTION	RESPONSIBILITY
6.0	- SIC 28 -	Chemicals, Allied Products (Cont'd)	
	6.10	Vinyl Chloride Monomer	
	6.11	Chlorine-Caustic Soda from Diaphragm Cells	
	6.12	Phosphoric Acid - Superphosphates	
	6.13	Isopropanol Synthesis	
	6.14	Styrene-Butadiene Rubber (SBR)	
	6.15	Nylon Fiber Synthesis	
	6.16	Styrene Monomer	
	6.17	Phenol/Acetone from Cumene	
	6.18	Ethylbenzene from Benzene Alkylation	
	6.19	Ethanol Synthesis	
7.0	- SIC 29 -	Petroleum & Coal Products	Dow Chemical
	7.1	General	
	7.2	Petroleum Refining	
8.0	- SIC 32 -	Stone, Clay, Glass Products	
	8.1	General	GE
	8.2	Portland Cement	Kaiser
	8.3	Lime	
	8.4	Glass Container	GE
	8.5	Flat Glass	GE
	8.6	Pressed and Blown Glass	
9.0	- SIC 33 -	Primary Metal Industries	Kaiser
	9.1	General	
	9.2	Integrated Steel Mill	
	9.3	Steel Specialty Plant	
	9.4	Non-Integrated Steel Mill	
	9.5	Alumina Plant	
	9.6	Aluminum Plant	
	9.7	Primary Copper	
	9.8	Primary Zinc	
	9.9	Primary Lead	
	9.10	Secondary Lead	

2. Food and Kindred Products (SIC 20)

2.1 General

This major group includes establishments manufacturing or processing foods and beverages for human consumption and certain related products. This industry is highly fossil fuel intensive with natural gas as the major fuel form. Fossil fuel accounts for over 80% of its energy use. Historically the growth of natural gas has been pronounced while electricity has increased its share of the total. This reflects an increased use of automation and freezing. The basic constraints on the industry have been to faster processing time, need for sterilization, packaging and the need to meet environmental requirements - these all tend to be energy intensive.

In the food industry, washing and cooking represent the most intensive thermal energy process and refrigeration is the largest mechanical process which represents over 25% of the total industrial refrigeration requirement. The temperatures associated with the process heat requirements are relatively low (< 300°F), particularly for those supplied by process steam.

In this study the top nine 4 digit SIC industries in the Food Sector were initially considered. An analysis and evaluation approach was established (Appendix A) which reduced these nine to the following five 4-digit industries for final consideration. These industries are presented in detail in the following section and Appendix C.

2011 - Meat Packing
2026 - Fluid Milk
2046 - Wet Corn Milling
2063 - Beet Sugar
2082 - Malt Beverages

2.2. Meat Packing (SIC 2011).

2.2.1 Process Description

These establishments primarily engaged in the slaughtering, for their own account or on a contract basis for the trade, of cattle, hogs, sheep, lambs, and calves for meat to be sold or to be used on the same premises in canning and curing, and in making sausage, lard, and other products. Establishments primarily engaged in killing, dressing, and packing poultry, rabbits, and other small game are classified in Industry 2016.

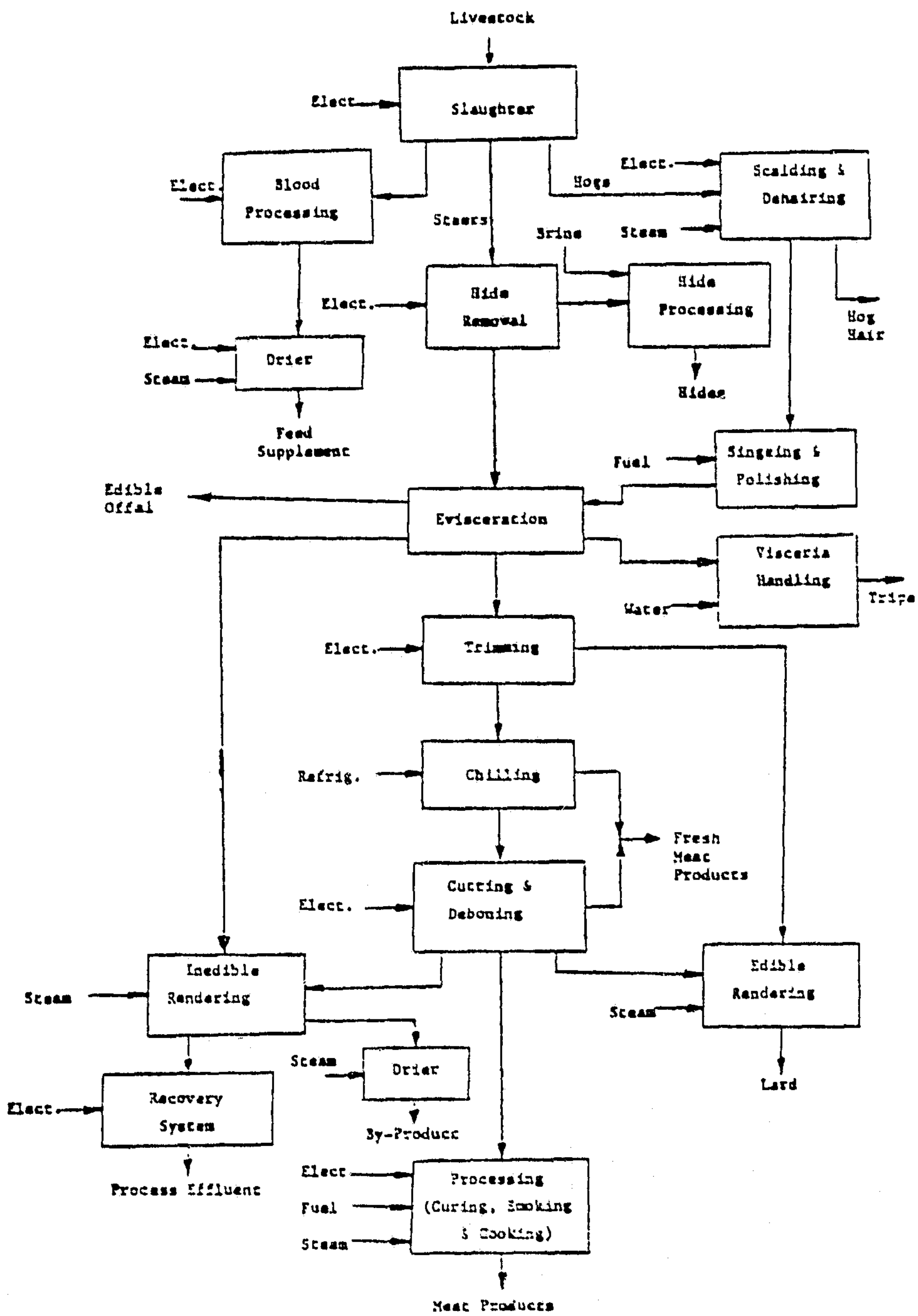
A typical process is shown in Figure 2.I which indicates the livestock (steers or hogs) as entering and the operations of removal of hide and internals. Following that the meat products are trimmed, deboned and processed (smoked, cooked, etc.). The major mechanical operation includes refrigeration. The major thermal processes include hot water and steam for rendering, clean up and smoking, cooking and curing.

Slaughtering operation is usally a one shift operation. However, carcasses are chilled overnight and storage areas are refrigerated. Refrigeration load is 24 hours per day. The industry is semi-seasonal. They run at full capacity in the Fall and Winter. During late Spring and Summer, fewer animals are available and some plants will operate only a few days per week.

Figure 2.I

2011 - MEAT PACKING PLANTS

PROCESS FLOW



2.2.2 Present and Future Plants

The distribution of plant size by employment and percentage of energy use is given in Figure 2.II. The plant size typical of the 1985-2000 year time frame is represented by a production level of approximately 50 x 10^6 lb/yr. These plants (100-500 employee range) currently represent about 34% of the energy consumed in SIC 2011. There are approximately 295 plants of this size or larger in the country now. Although growth rate has been predicted at over 11%/yr, this may not show up as a significant increase in number of plants. There appears to be a surplus of slaughtering capacity in the industry.

Since World War II, the trend has been for movement of plants from large central slaughtering areas (e.g. Chicago) to areas near where animals are grown. An additional 20-40 plants are estimated by the year 2000 of this typical size due to expansion of smaller plants and new construction. Cogeneration potential is good because of electrical use for refrigeration and large steam hot water requirements.

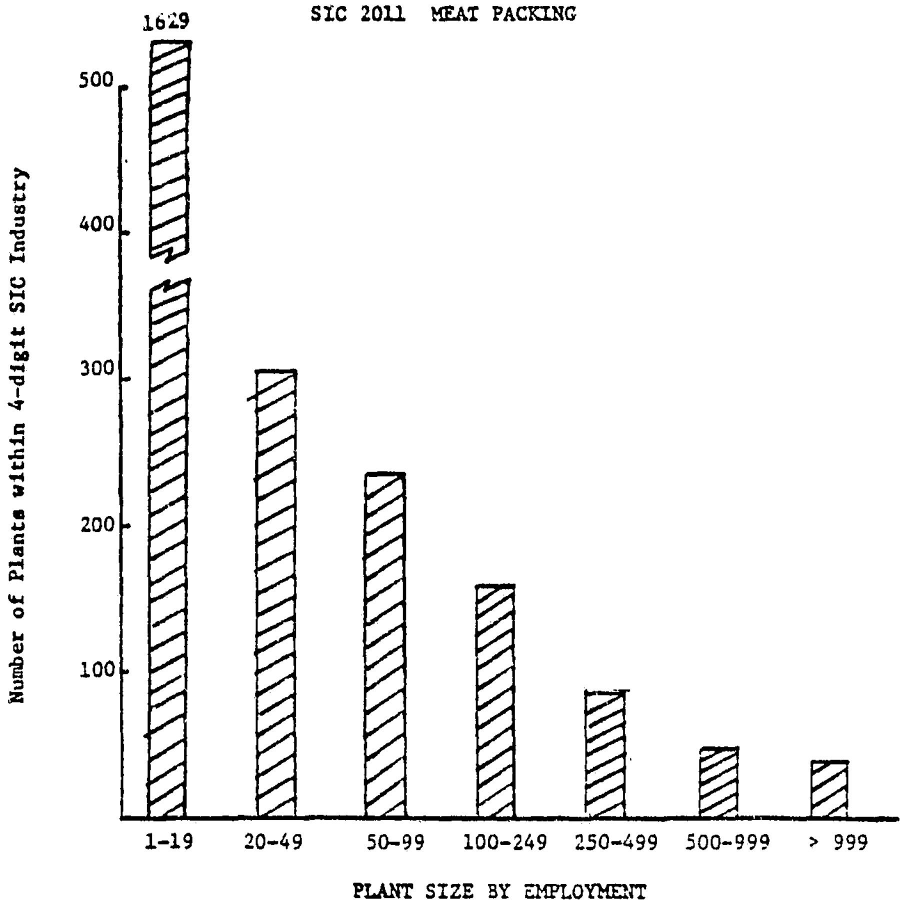
2.2.3 Energy Requirements

The energy requirements are presented in Table 2.I which presents significant data for the application of Cogeneration Technologies. It is estimated that this industry uses 117 x 10^{12} BTU/yr of the national energy in 1978 and will approach 191 x 10^{12} BTU/yr by the year 2000. The primary fuel used is gas which represents 64.3% of the fossil fuel used by this industry.

This industry uses approximately 1900 BTU fossil fuel per pound of meat products produced.

Figure 2.II

SIC 2011 MEAT PACKING



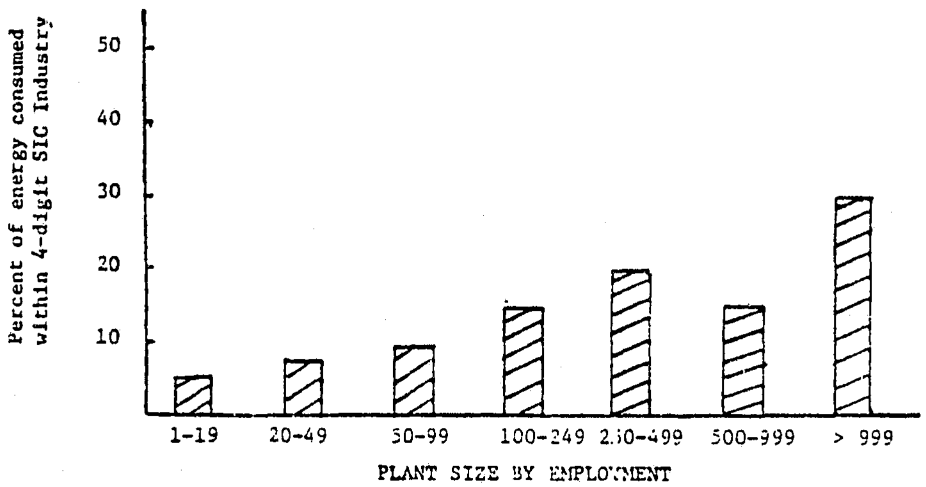


Table 2.I

A. Plant Name/Size: 2011-Meat Packing (Typical of the 100-500 employee range representing 34% of energy of 2011)

B. Products:

Product	lb/yr, etc.
Meat Products	48×10^6
Lard & Tallow	1.3×10^6
Hide	3.8×10^6

C. Plant Kilowatt Requirements: Average 1940 kW; Peak 2330 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
24×10^3	@	15	25% of steam condensate	180°F
	@			
	@			

E. Other Heat to Process (Describe):

Hot water @ 140°-180° assumed made from 40% of the 15 psig steam. Singeing and smoking, cooking and curing require approximately 2×10^6 BTU/hr.

F. Plant Hours of Operation at Average Conditions: 2100 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Refrig. Comp.	320	380	-	-	electric

H. Operational Considerations:

Slaughtering operation is usually a one shift operation. However, carcasses are chilled overnight and storage areas are refrigerated. Refrigeration load is 24 hours per day. Industry is semi-seasonal. They run at full capacity in the Fall and Winter. During late Spring and Summer, fewer animals are availalbe and some plants will operate only a few days per week.

I. Waste Heat Streams:

lb/hr	Temp.	Description
118,000	400-500°F	Stack from boiler
320	200-220°F	Vapor from blood dryer
7,000	400-550°F	Stack from singeing
34,000	200°F	Vapor from inedible rendering dryer
21,000	400-550°F	Stack from smoking & cooking

Plant Name/Size: 2011-Meat Packing - (Typical of the 100-500 employee range representing 34% of energy of 2011)

		National % Distribution	Using Same Distribution for Typical Plant.
J. Fuels:	Primary Fuel	Gas / (64.3%)	27.4 mil. Btu/hr (HHV)
	Secondary Fuel	Other / (14.5%)	6.2 mil. Btu/hr (HHV)
	By-product Fuel	Coal / (11.6%)	4.9 mil. Btu/hr (HHV)
		Oil (9.6%)	4.1 " " "

K. Fuels Discussion:

90% of fuel used to generate steam or hot water. The remainder for singeing, smoking, or vehicle transportation. This 10% generally requires special fuels, but again this is a small fraction of total.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Approximately 295 plants of this size or larger in the country now. Although growth rate has been predicted at over 11%/yr, this may not show up as a significant increase in number of plants. There appears to be a surplus of slaughtering capacity in the industry.

M. Application Discussion:

Since World War II, the trend has been for movement of plants from large central slaughtering areas (e.g. Chicago) to areas near where animals are grown. Thus moderni-zation of large plants in animal production areas and building of an estimated 20-40 plants by year 2000 of this typical size due to expansion of smaller plants and new construction. Cogeneration potential good because of electrical use for refrigeration and large steam hot water requirements.

N. Preferred Economic Criteria: Estimated criteria of over 8% return on net worth.

O. Economic Discussion:

Capital expenditures for equipment and new structures range from $150-250 million per year.

P. Duty Cycle and Maintenance Philosophy:

Refrigeration operates on 24 hour cycle while basic plant operations are on 1 shift/day.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

For typical plant discussed here, average electrical load from 8 am to 4 pm is 1940 Kw and from 4 pm to 8 am the average load is 240 Kw. The steam rate of 24,000 lb/hr is relatively constant from 8 am to 4 pm as are the waste streams.

Plant Name/Size: 2011-Meat Packing

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Estimated at $200-400 million/yr.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
The attached flow sheet is typical for most plants and probably will not change in the future.

T. What is the national capacity for producing this product

Now in 1978 Estimated 35,000 x 10^6 lb/yr (Production assumed to be ~ 70% of capacity)

In 2000 40-50,000 x 10^6 lb/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.
Major factors may be substitution for natural gas in boilers to maintain production and also the eating habits of public - if there is reduction in diet of red meats.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)
Increased consumption has been projected at over 11%/yr but may be better correlated with GNP or disposable income. However, this may be over stated due to change in diet of public.

W. National energy consumed by this process (fossil and elec. x 3 = total BTU/yr)

In 1978 117 x 10^{12} BTU/yr

In 1985 132 x 10^{12} BTU/yr

In 2000 191 x 10^{12} BTU/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.
Size of plant described is typical of 100-500 employee range (30-80 x 10^6 lb/yr production which appears to be typical of the future.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See attached Process Flow Diagram and Summary Sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

5.5%

This is a percentage of value added which does not include cost of raw materials or profits but all other costs.

2.3 Fluid Milk (SIC 2026)

2.3.1 Process Description

These establishments are primarily engaged in processing (pasteurizing, homogenizing, vitamizing, bottling) and distributing fluid milk and cream and related products including cottage cheese. The process is shown in Figure 2.III in which whole milk is received in the plant and fluid milk and cottage cheese produced. Again refrigeration is the main mechanical process although packaging requires significant electrical requirements. The Pasteurization process and the cooker (in which skim milk) is produced requires the major thermal energy.

Not all plants will make cottage cheese. However, some plants will make quite a variety of products including cottage cheese, ice cream, etc. Fluid milk operations are generally one shift per day, five days per week. They are year round operations.

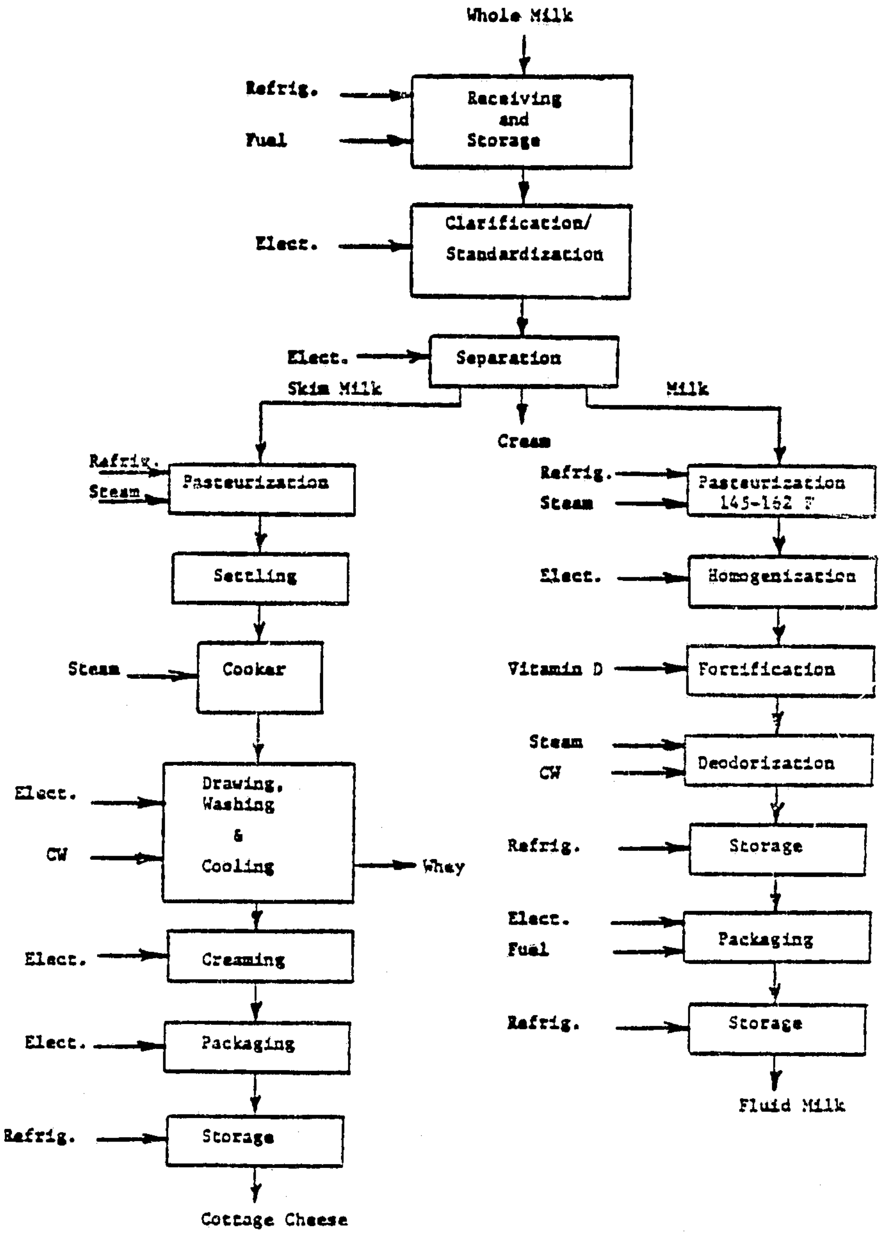
2.3.2 Present and Future Plants

The distribution of plant size by employment and percentage of energy use is given in Figure 2.III. The plant size typical of the 1985-2000 year time frame is represented by a production level of approximately 50 x 10^6 lb/yr. These plants (50-250 employee range) currently represent about 63% of the energy consumed in SIC 2026. Per capita consumption of fluid milk is fairly constant and therefore total consumption will vary with the population. Projections are for 1.5 to 1.7% growth rate per year. Construction of new plants in the dairy industry in the past few years appears to be mainly for plants for other dairy

Figure 2.III

2026 - FLUID MILK

PROCESS FLOW



products (cheese, etc.). The trend in the industry is for closing of smaller local plants and upgrading of remaining plants. The plants that are closed are small enough that they don't significantly affect industry capacity. Approximately 735 plants of this typical size or larger are in the country now. Expansion of present small plants, increasing capacity and construction of new plants of this size may represent an additional 20 to 50 new plants by the year 2000. The cogeneration potential is good because of low presure steam and hot water requirements along with the electric requirements. However, payback is a strong function of the single shift operation.

2.3.3 Energy Requirements

The energy requirements are presented in Table 2.II which presents significant data for the application of Cogeneration Technologies. It is estimated that this industry uses 71×10^{12} BTU/yr of the national energy in 1978 and will approach 101×10^{12} BTU/yr by the year 2000. The primary fuel used is natural gas which represents 42% of the fossil fuel used by this industry.

This industry uses approximately 600 BTU fossil fuel per pound of milk products produced.

Figure 2.IV

SIC 2026 FLUID MILK

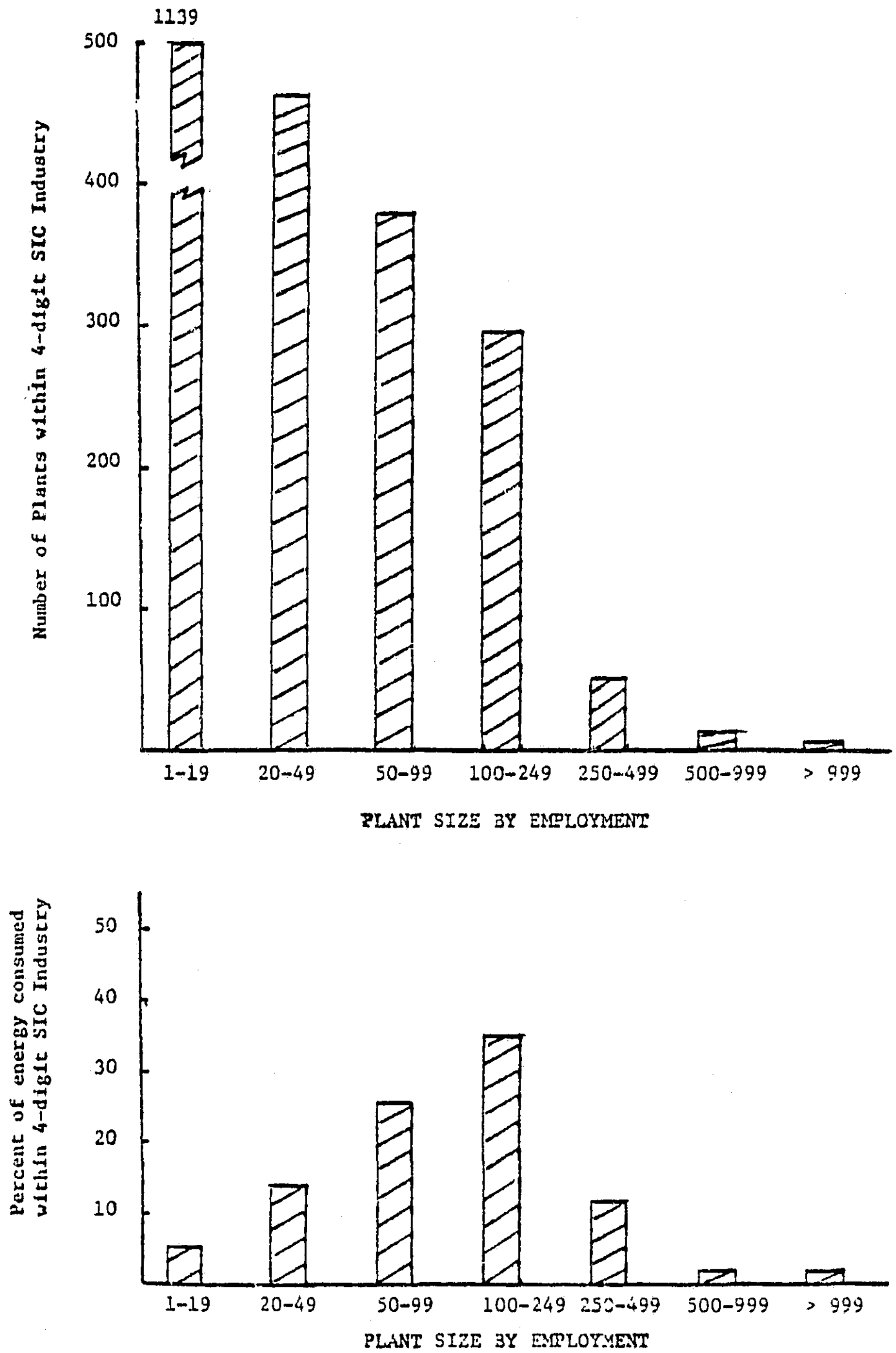


Table 2.II

Typical plant of the 50-250 employee range representing 63% of energy consumed in 2026. Typical

A. Plant Name/Size: 2026-Fluid Milk - plant production at 48 x 10^6 lb/yr of product.

B. Products:

Product	lb/yr, etc.
Fluid Milk	35 x 10^6
Cottage Cheese	13 x 10^6

C. Plant Kilowatt Requirements: Average 1310 kW; Peak 1570 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
11,000	@	15	50%	180°
	@			
	@			

E. Other Heat to Process (Describe):

Hot water produced from steam in the 160°F range.

F. Plant Hours of Operation at Average Conditions: 2100 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
No single large motor or drives.				

H. Operational Considerations:

Not all plants will make cottage cheese. However, some plants will make quite a variety of products including cottage cheese, ice cream, etc. Fluid milk operations are generally one shift per day, five days per week. They are year round operations.

I. Waste Heat Streams:

lb/hr	Temp.	Description
10,000	120-150°F	Waste water
27,000	400-500°F	Boiler stack

Plant Name/Size: 2026- Fluid Milk

		National % Distribution		Using Same Distribution for Typical Plant	
J. Fuels:	Primary Fuel	Gas	/ (42%)	6.0	mil. Btu/hr (HHV)
	Secondary Fuel	Other / Oil	/ (39%) / (18%)	5.6 / 2.6	mil. Btu/hr (HHV)
	By-product Fuel	Coal	/ (1%)	.1	mil. Btu/hr (HHV)

K. Fuels Discussion:

Fuels used predominantly for steam production. Other type fuels used such as gas, propane, etc. used for vehicles and in most cases fuels not classified by Census of Mfg. but are used for steam production.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Per capita consumption of fluid milk is fairly constant and therefore total consumption will vary with the population. Projections are for 1.5 to 1.7% growth rate per year. Construction of new plants in the dairy industry in the past vew years appears to be mainly for plants for other dairy products (cheese, etc.). The trend in the industry

M. Application Discussion:

is for closing of smaller local plants and upgrading of remaining plants. The plants that are closed are small enough that they don't significantly affect industry capacity. Approximately 735 plants of this typical size or larger are in the country now. Expansion of present small plants, increasing capacity and construction of new plants of this size may represent an additional 20 to 50 new plants by the year 2000. The cogeneration potential is good because of low presure steam and hot water requirements along with the electric requirements. However, payback is a strong function of the single shift operation

N. Preferred Economic Criteria: Return on net worth of 11.4%.

O. Economic Discussion:

Capital expenditures for equipment and new structures range from $125 to 175 million per year.

P. Duty Cycle and Maintenance Philosophy:

A fraction of the refrigeration operates on a 24 hour cycle. Cleaning operation significant at end of day period and at start up.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

Approximately 50 Kw load on a 24 hour basis and the remainder 1260 Kw during the eight hour shift. The steam and waste stream profiles are relatively level for eight hours.

Plant Name/Size: 2026 - Fluid Milk

R. Describe the level of capital investment in this industry. (1985-2000 time period)
In the year 2000, it is estimated that the capital expenditure will range from \$200 to \$300 million per year.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
The attached flow sheet is fairly typical, although not all plants will make cottage cheese, etc. The process will stay basically the same for some time to come.

T. What is the national capacity for producing this product

Now in 1978	60-70,000 x 10^6 lb/yr.
In 2000	80-90,000 x 10^6 lb/yr.

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.
Any major changes would be created by form of milk products. Such as dry milk, etc. and therefore packaging may change. Possible shift to sterile containers which require a slight increase in temperatures to 260°-270°F but no rapid changes predicted.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)
Per capita consumption of fluid milk is fairly constant and therefore total consumption will vary with the population. Projections are for a 1.7% growth rate.

W. National energy consumed by this process (fossil plus elec. x 3 = total BTU/yr)

In 1978	71 x 10^{12} BTU/yr
In 1985	80 x 10^{12} BTU/yr
In 2000	101 x 10^{12} BTU/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.
The size of the plant described here is typical of the 50-250 employee range (40-60 x 10^5 lb/yr per plant) which appears to be typical of plants of the future and also represents the size range consuming the largest fraction of energy.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See attached Process Flow Diagram and Summary Sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.
5%
This is a percentage of value added which does not include cost of raw material or profits but includes all other costs.

2.4. Wet Corn Milling (SIC 2046)

2.4.1 Process Description

These establishments are primarily engaged in milling corn or sorghum grain (milo) by the wet process, and producing starch, syrup, oil, sugar, and byproducts, such as gluten feed and meal. Establishments primarily engaged in manufacturing table syrups from corn syrup and other ingredients, and those manufacturing starch base dessert powders, are classified in Industry 2099. The process is shown in Figure 2.V in which shelled corn enters the process. It is then seperated, ground, washed and passed through a centrifugal separator to produce a starch, which is processed to produce corn syrup and other products. The evaporators, extractors and drying operatons are the primary thermal energy users while the centrifugal process represents a large mechanical requirement.

There is very large electric self generation (on a national basis) in this industry. The national average is about 57%.

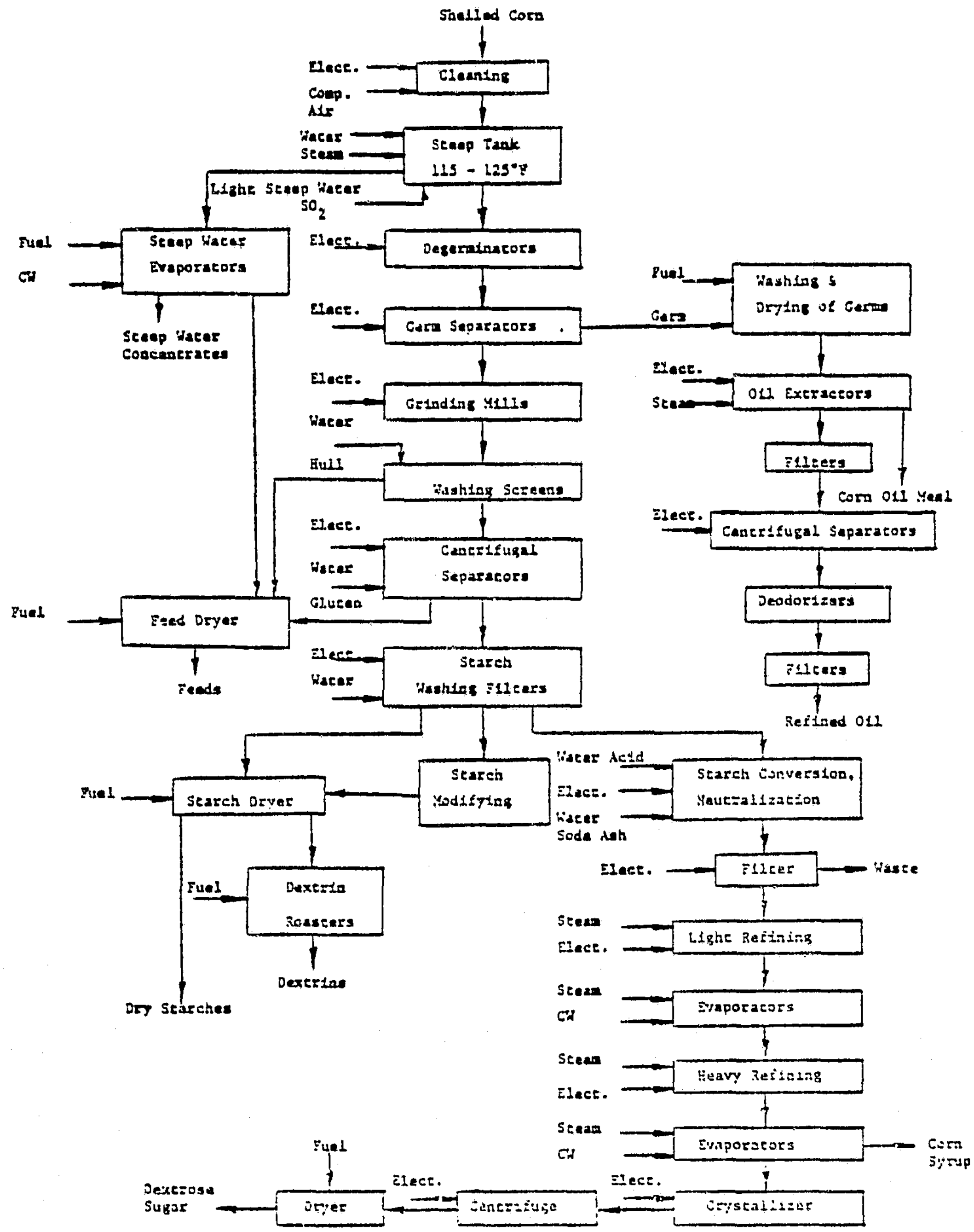
2.4.2 Present and Future Plants

The distribution of plant size by employment and percentage of energy use is given in Figure 2.VI. The plant size typical of the 1985-200 year time frame is represented by a production level of approximately 1.4 x 10^9 lb/yr of corn processed. These plants (greater than 500 employee range) currently represent 84% of the energy consumed in SIC 2046.

Figure 2.V.

2046 - WET CORN MILLING

PROCESS FLOW



Approximately 9 large plants now account for 84% of energy use. Growth rate is projected at 8.5% for 1978 as corn syrup production increases. With new capacity installed for corn syrup production, production should revert to the historical averages - e.g. 2/3 of GNP increase. On this basis, and the fact the new large plants are smaller than existing ones, 15 large plants are estimated for 1990-2000.

While large plants continue to be most significant, with present capacity averaging 85,000 bushels/day. This and the projected growth rates give rise to the number of large plants estimated above for 1990. Most new plants make corn syrup - this is not true of all older plants - this is not however a high energy process. There is excellent cogeneration potential because of 24 hour operation.

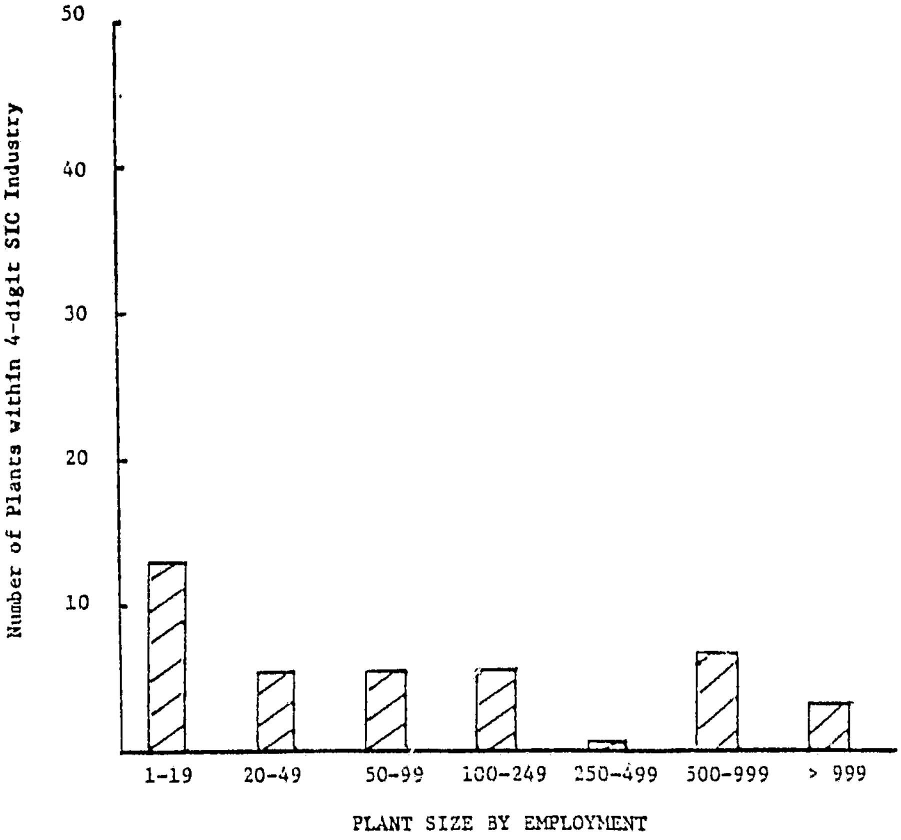
2.4.3 Energy Requirements

The energy requirements are presented in Table 2.III which presents significant data for the application of cogeneration Technologies. It is estimated that this industry uses 10×10^{13} BTU/yr of the national energy in 1978 and will approach almost 16×10^{13} BTU/yr by the year 2000. The primary fuel used is natural gas which represents 57% of the fossil fuel used by this industry.

This industry uses approximately 6100 BTU of fossil fuel per pound of corn processed.

Figure 2.VI

SIC 2046 WET CORN MILLING



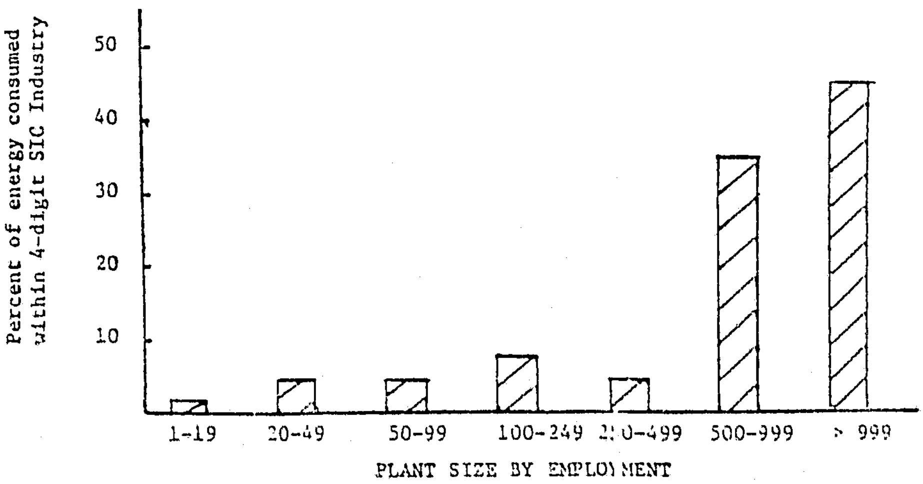


Table 2.III

A. Plant Name/Size: 2046-Wet Corn Milling, 84% of energy in plants with 500 or greater employees.

B. Products:

Product	lb/yr, etc.
Corn Oil	1.4×10^9 lb/yr of corn processed
Corn Oil Meal	
Corn Syrup	

C. Plant Kilowatt Requirements: Average 28.5 MW; Peak 35.6 MW;
(Of this approx. 57% is self generated - national avg.)

D. Steam Requirements (Process & Heating):

	lb/hr	@	psig,	Returns %,	Temp. of Returns
Process	41.9×10^4	@	15	47% of steam cond. returned	180°F
Heating	3.8×10^4	@	15		
Cleanup	20.2×10^4	@	15		
On-Site Generation	10.5×10^4	@	500		

E. Other Heat to Process (Describe):
There are significant direct heat requirements in the drying and roasting operations (see process flow sheets)

Feed Dryer - 10.5×10^7 Btu/hr
Dextrin Roaster 2.9×10^7 Btu/hr

Overall, the ratio of steam required to direct heat is 4.8.

F. Plant Hours of Operation at Average Conditions: 6600 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Approx. 9 distinct large hp loads all about the same hp. (see process flow sheets)	1850 HP				Electric Motors

H. Operational Considerations:
There is very large self generation in this industry - as a national average 57% of electrical requirement is self generated - it is assumed here that 57% plant requirements are self generated.

I. Waste Heat Streams: There is some additional waste heat in cooling water (95-110°F) and moist air (200°F) from dryers - these have not been included due to inaccessibility of recovery.

	lb/hr	Temp.	Description
(gaseous)	10^5	400°F	Feed Dryer Stack
(gaseous)	3×10^5	450°F	Electric Generation
(gaseous)	5×10^5	450°F	Boiler Stack
(liq.)	4×10^5	180°F	Non Returned Condensate

Plant Name/Size: 2046-Wet Corn Milling, 84% of energy in plants with 500 or greater employees.

National Fuel Distribution (%)			Typical Plant Size Distribution	
J. Fuels: Primary Fuel	Nat. Gas	/ (57%)	740	mil. Btu/hr (HHV)
Secondary Fuel	Coal Oil	/ (32%) (9%)	415 120	mil. Btu/hr (HHV)
By-product Fuel	Other	/ (1.5 %)	20	mil. Btu/hr (HHV)

K. Fuels Discussion:

Natural gas is used in the direct heat, drying and roasting operations and as boiler fuel. The other fuels are exclusively boiler fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Approx. 9 large plants now account for 84% of energy use. Growth rate is projected at 8.5% for 1978 as corn syrup production increases. With new capacity installed for corn syrup production, production should revert to the historical averages - e.g. 2/3 of GNP increase. On this basis, and the fact the new large plants are smaller than existing ones (see below) 15 large plants estimated for 1990.

M. Application Discussion:

While large plants continue to be most significant, with present capacity averaging 85,000 bushels/day - new plants (while still large) now average 35,000 bushels/day. This and the projected growth rates give rise to the number of large plants estimated above for 1990. Most new plants make corn syrup - this is not true of all older plants this is not however a high energy process. There is excellent cogeneration potential because of 24 hour operation.

N. Preferred Economic Criteria: Estimated criteria of over 9% return on net worth.

O. Economic Discussion:

Estimated capital expenditures range from $50 - 100/yr for the 1977-1979 time frame.

P. Duty Cycle and Maintenance Philosophy:

Most of the operations in the plant are 24 hours per day. With new separation techniques it may be possible in the future to do all separations in one shift and store.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

For a typical plant the average electrical load is fairly constant at 28.5 MW for 24 hrs./day. The total steam rate is also fairly constant at 65,000 #/hr. At 6600 hr/yr of operation - the plants operate at 5-6 days per week.

Plant Name/Size: 2046-Wet Corn Milling, 84% of energy in plants with 500 or greater employees.

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Est. \$85-150 million/yr.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Process is unchanged.

T. What is the national capacity for producing this product

Now in 1978 1.7×10^{10} Lb/yr.

In 2000 3.9×10^{10} Lb/yr.

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.
Most new plants now make corn syrup as an additional product - this additional step is not energy intensive. No other changes are anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)
Historically the product grew at 2/3 GNP, however since corn syrup capacity has been added growth rate has been higher than this - it is anticipated that by 1990, 2/3 GNP growth will return.

W. National energy consumed by this process

In 1978 10.4×10^{13} BTU/yr.

In 1985 14.1×10^{13} BTU/yr.

In 2000 15.9×10^{13} BTU/yr.

X. Describe the typical size of this plant today and how that will change in 1985-2000.
Present plant sizes for large plants (greater than 500 employees) is 85,000 bushels/day - This will decrease to 35,000 bushels/day.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See attached Process Flow Diagram and Summary Sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

12%

This is a percentage of value added which does not include cost of raw materials or profits but does include all other costs. Numbers are from 1972 census with correction to 1978.

2.5 Beet Sugar Refining (SIC 2063)

2.5.1. Process Description

These establishments are primarily engaged in the manufacturing of sugar from sugar beets. The process is shown in Figure 2.VII in which the beets eneter the process and then are washed and sliced and the juice and pulp separated. Then a series of steps including evaporation, centrifuging, drying and packaging take place to produce sugar and molasses. The centrifuging is the largest mechanical requirement with the slicing, screening, etc. representing large electrical requirements also. The kiln dryer is the largest fuel user other than the steam/hot water boiler. The heaters are large steam users.

This is a 24 hour operation for 5 or 6 days per week for 4 or 5 months. There is also a very large electric self generation. The national ratio of self generation to purchased electric energy is 2.2.

2.5.2. Present and Future Plants

The distribution of plant size by employment and percentage of energy use is given in Figure 2.VIII. The plant size typical of the 1985-2000 year time frame is represented by a production level of approximately 200 x 10^6 lb/yr. The plants (100 to 500 employee range) currently represents 86% of the energy consumed in SIC 2063.

The number of plants will remain stable. There has not been extensive plant building in this industry. The product demand should be stable, with any increases being at the rate of population growth. In the 1985-2000 year time frame there will be approximately 52 plants.

Figure 2.VII
2063 - BEET SUGAR
PROCESS FLOW

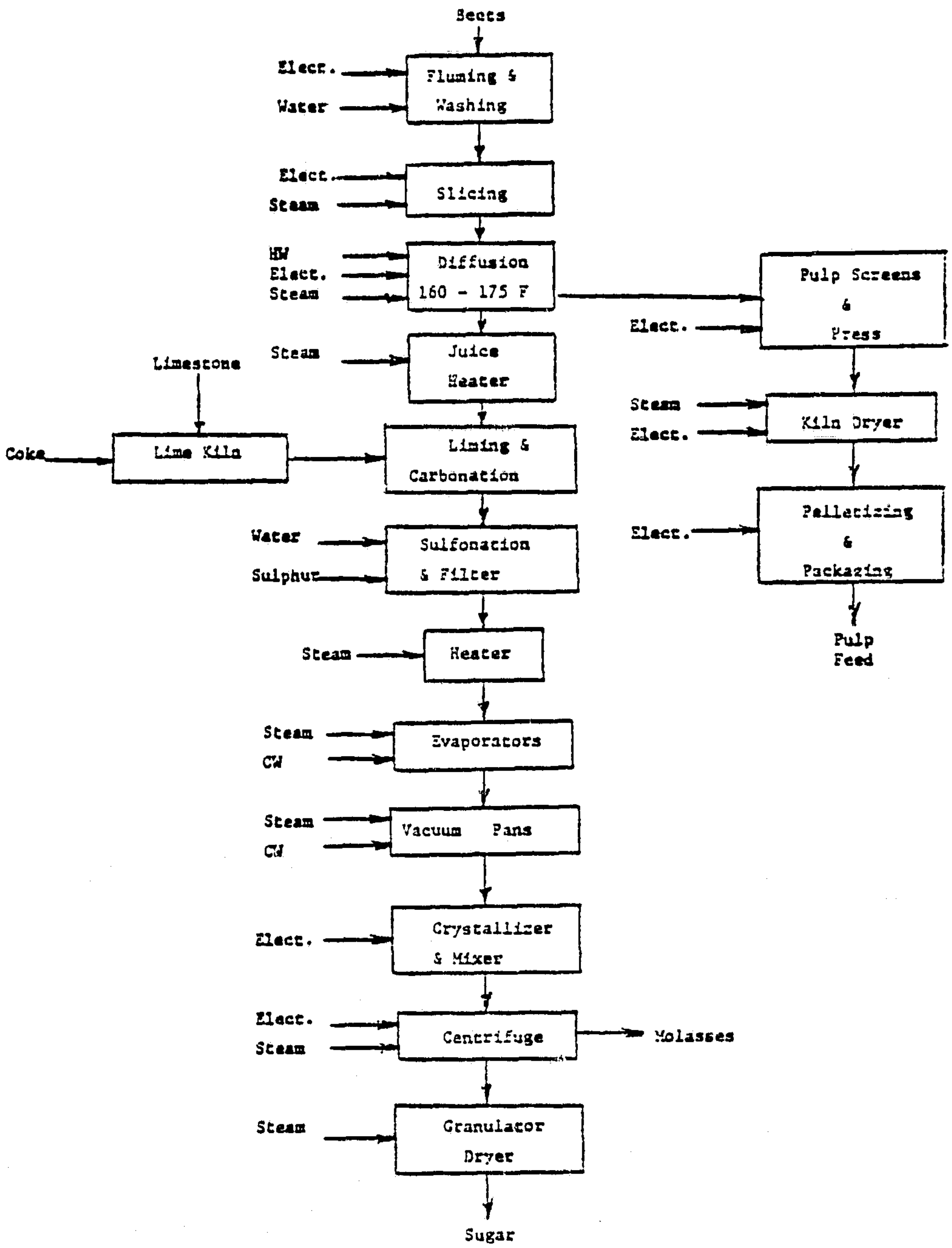
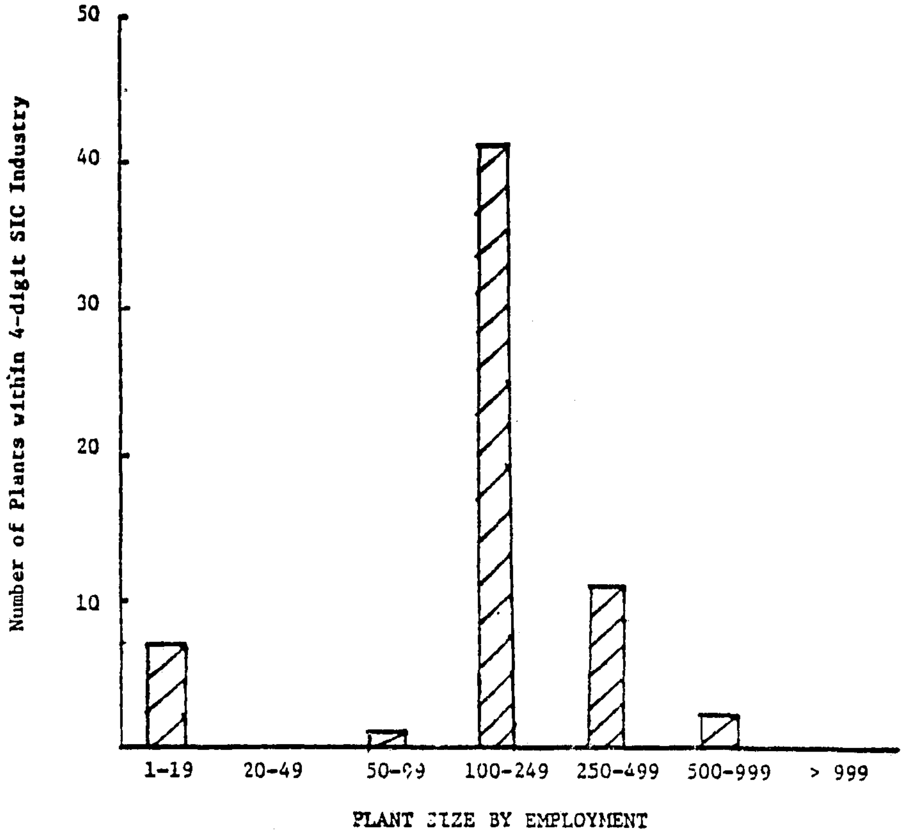
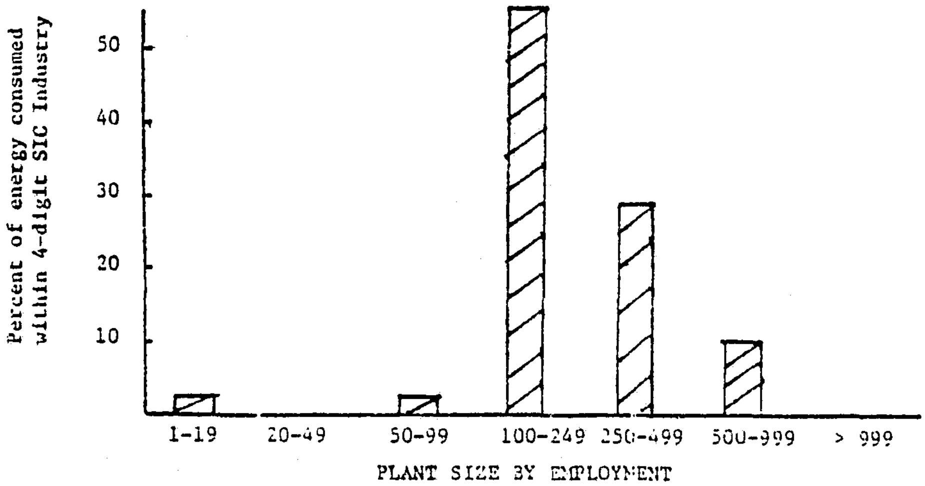


Figure 2.VIII

SIC 2063 BEET SUGAR INDUSTRY





2.5.3. Energy Requirements

The energy requirements are presented in Table 2.IV which presents significant data for the application of cogeneration technology. It is estimated that this industry uses 7.5×10^{13} BTU/yr of the national energy in 1978 and will approach almost 13×10^{13} BTU/yr by the year 2000. The primary fuel used is natural gas which represents 42% of the fossil fuel used by this industry.

This industry uses approximately 7900 BTU of fossil fuel per pound production.

Table 2.IV

A. **Plant** Name/Size: 2063- Beet Sugar, Typical plant in 100-500 employee range which accounts for 86% of energy.

B. **Products:**

Product	lb/yr, etc.
Beet Sugar	200×10^6 Lb/yr.

C. **Plant** Kilowatt Requirements: Average 4700 kW; Peak 5800 kW

D. Steam Requirements (Process & Heating):

	lb/hr	@	psig,	Returns %,	Temp. of Returns
Process Steam	26×10^4	@	15		
Clean Up	2.9×10^4	@	15	62%	180°F
Space Ht.	1.2×10^4	@	15	returned	
Self Generation	2.2×10^4		500		

E. Other Heat to Process (Describe):

There are two significant direct heat requirements:
Kiln Dryer 12.2×10^7 Btu/hr.
Lime Kiln 2.2×10^7 Btu/hr.
The ratio of steam to direct heat required is 2.3.

F. **Plant** Hours of Operation at Average Conditions: 2800 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Centrifuge	1350HP	-	-	-	Motor
All other	motor loads				
are in the	range 300-1000 HP.				

H. Operational Considerations:

24 hour operation - 5 or 6 days per week for 4 - 5 months. Very large self generation - nationally the ratio of self generation to pruchased is 2.2.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(gaseous)	8×10^5	450°F	Boiler Stack
(gaseous)	10^5	450°F	Electric Gen
(Liq.)	1.3×10^5	180°F	Non-Returned Condensate
(gaseous)	10^6	400°F	Dryer Stacks

Plant Name/Size: 2063- Beet Sugar, Typical plant in 100-500 employee range which accounts for 86% of energy.

		National % Distribution			Distribution for Typical Plant	
J. Fuels:	Primary Fuel	Nat. Gas	(42%)	/	238	mil. Btu/hr (HHV)
	Secondary Fuel	Coal	(39%)	/	221	mil. Btu/hr (HHV)
	By-product Fuel	Other	(13%)	/	74	mil. Btu/hr (HHV)
		Oil	(6%)		34	mil. Btu/hr (HHV)

K. Fuels Discussion:

The natural gas is used in the kiln dryer and as boiler fuel, coal is used as coke in the Lime Kiln and also as boiler fuel and all other fuels are boiler fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
52	Sugar Beet Growing Areas	Excellent - 24 hour operation

M. Application Discussion:

The number of plants will remain stable. There has not been extensive plant building in this industry. The product demand should be stable, with any increases being at the rate of population growth.

N. Preferred Economic Criteria: 9 - 10% of Net Worth

O. Economic Discussion:

Capital expenditures in this industry were $35 x 10^6 in 1972. In general, new plant construction is low.

P. Duty Cycle and Maintenance Philosophy:

Plants operate for 24 hours - 5 or 6 days/week. Operation is seasonable - starting in the late summer and ending in the winter. In Michigan, for example, plants operate 110 - 120 days/yr.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

All electric and thermal loads are constant at levels given in C & D over 24 hour periods for 5 - 6 days per week. It is however seasonal - 4 - 5 months/yr.

Plant Name/Size: 2063- Beet Sugar, Typical plant in 100-500 employee range which accounts for 86% of energy.

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$100 - 150 x 10^6/yr. in 1990 time frame.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Process will be unchanged.

T. What is the national capacity for producing this product

Now in 1978 18 x 10^9 Lb/yr.

In 2000 30 x 10^9 Lb/yr.

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes are anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period) Per capita consumption of sugar has remained constant for some time. However competition from other sweeteners (corn syrup, etc.) is active. It is expected beet sugar will maintain its share of the sucrose market - and growth will be at a rate not faster than population (2-3%/yr). The process itself should be unchanged.

W. National energy consumed by this process

In 1978 7.5 x 10^{13} BTU/yr.

In 1985 9.3 x 10^{13} BTU/yr.

In 2000 12.5 x 10^{13} BTU/yr.

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Typical size is in the 200 x 10^6 lb/yr. range - this should not change - the mix of plant sizes should remain stable.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See Process Flow Sheets.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

In 1972, neglecting raw material costs this was 9.8%. It is estimated that this has climbed to 13% in 1978 based on energy cost that has increased more rapidly than labor costs.

2.6 Malt Beverages (SIC 2082)

2.6.1. Process Description

These establishments are primarily engaged in manufacturing all kinds of malt beverages. The process is shown in Figure 2.IX in which barley malt enters the process and is cooked, filtered and screened. Dry feedstuff is produced and the brew is fermented, aged filtered, bottled and pasteurized producing beer. The refrigeration, grinding mill and compressor for bottling represent the major mechanical loads while cooking, drying and pasteurizing require the major thermal energy requirements.

Fermentation and aging are a continuous process. Labor required is low, but the fermenting and ageing cellars are refrigerated continuously. Brew house operations vary from one to three shift operation. In older breweries, one shift operation is common. Bottling is often a one shift operation, although in larger plants two or three shifts may be used. The operation of a brewery is determined by the amount of fermenting and storage capacity. With todays' high speed filling machinery (1500 bottles or cans/minute) one shift for bottling may handle the plant capacity.

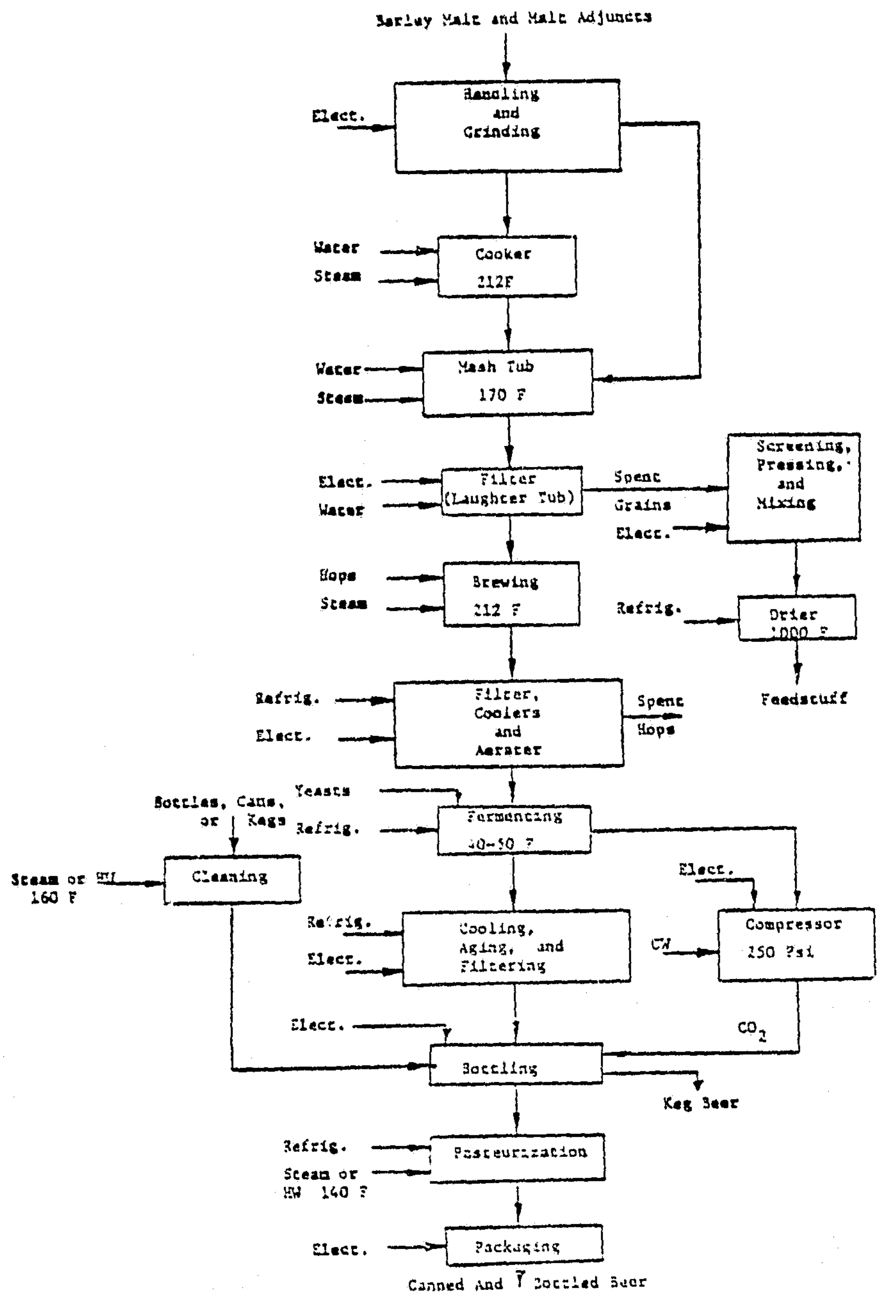
2.6.2. Present and Future Plants

The distribution of plant size by employment and percentage of energy use is given in Figure 2.X. The plant size typical of the 1985-2000 year time frame is represented by a production level of approximately 800 x 10^6 lb/yr. The plants (greater than 500 employee range) currently represent 56% of the energy consuemd in SIC 2082.

Figure 2.IX

2082 - MALT BEVERAGES

PROCESS FLOW



Growth rate for malt beverages has been estimated at about 4% per year. More recent estimates are a growth rate of about double this. However, the higher figure is based on the fact that there has been a high increase in the last two years. It may be too early to determine whether the high rate will continue but it has held for the last few years. In general, the large companies are taking over the market. These companies have been building large breweries and in some cases super large industries. With approximately 24 plants of the typical size or larger in operation now, it is anticipated that in the years 1990-2000 another 10-20 plants in this size range iwll be constructed or expanded to this size. The cogeneration potential is good because of 24 operation and electric-steam demand.

2.6.3. Energy Requirements

The energy requirements are presented in Table 2.V which presents significant data for the application of cogeneration technology. It is estimated that this industry uses 750×10^{11} BTU/yr of the national energy in 1978 and will approach about 1900×10^{11} BTU/yr by the year 2000. The primary fuel used is natural gas which represents 63% of the fossil fuel used by this industry.

This industry uses approximately 1300 BTU of fossil fuel per pound of production.

Figure 2.X

SIC 2082 MALT BEVERAGES

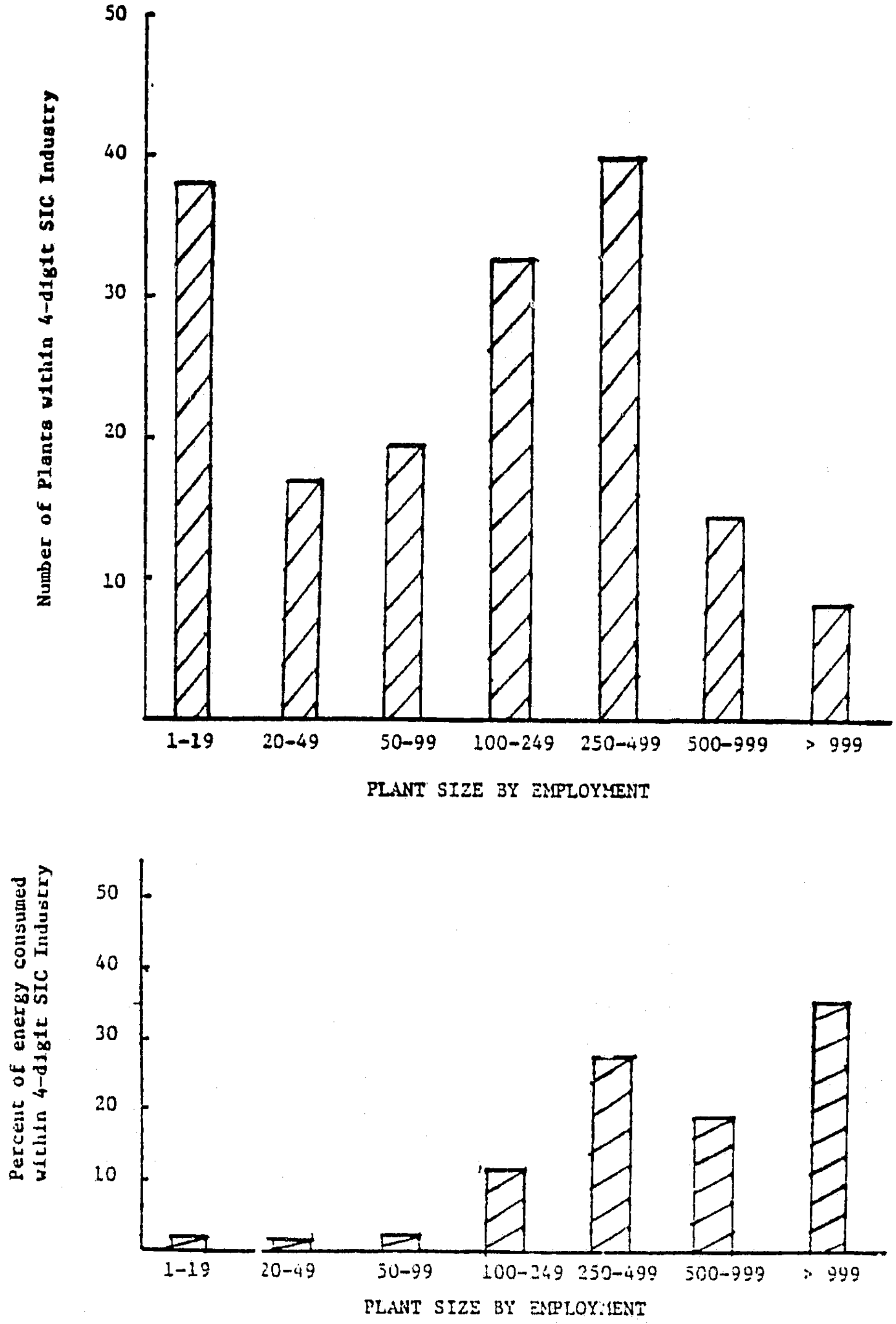


Table 2.V

A. Plant Name/Size: 2082-Malt Beverages (Typical of the larger plants with greater than 500 employees which currently represent 56% of the energy consumed in 2082).

B. Products:

Product	lb/yr, etc.
Beer	800×10^6
Dry Feedstuff	3.2×10^6

C. Plant Kilowatt Requirements: Average 6040 kW; Peak 7250 kW

During bottling and packaging

D. Steam Requirements (Process & Heating): 2 shifts

	lb/hr	@	psig,	Returns %,	Temp. of Returns
(process)	86,000	@	15	25%	180°
(generate elec.)	6,500	@	500	100%	180°
		@			

E. Other Heat to Process (Describe):

Hot water requirements are 160° - 180° and are produced from steam. It represents 60% of the steam requirements.
Drying of wet feedstuff at 175° - 225° by burning fuel.

F. Plant Hours of Operation at Average Conditions: 6600 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Grinding Mill	640	-	-	-	elect.
CO_2 Compressor	400	-	-	-	elect.
Refrigeration	2300	-	-	-	elect.

H. Operational Considerations:

Fermentation and aging are a continuous process. Labor required is low, but the fermenting and ageing cellars are refrigerated continuously. Brew house operations vary from one to three shift operation. In older breweries, one shift operation is common. Bottling is often a one shift operation, although in larger plants two or three shifts may be used. The operation of a brewery is determined by the amount of fermenting and storage capacity. With todays' high speed filling machinery (1500 bottles or cans/minute) one shift for bottling may handle the plant capacity.

I. Waste Heat Streams:

lb/hr	Temp.	Description
172,000	400-550°	Process Boiler Stack
16,000	400-550°	Boiler Stack for elec. generation
240,000	600-700°	Dryer Stack
70,000	150°	Waste Water Including Non Returned Cond.

Plant Name/Size: 2082 - Malt Beverages

	National Fuel Distribution (%)		Typical Plant Dist.
J. Fuels: Primary Fuel	Gas (63%)	/	100 mil. Btu/hr (HHV)
Secondary Fuel	Oil (25%)	/	40 mil. Btu/hr (HHV)
By-product Fuel	Coil (8 %)	/	15 mil. Btu/hr (HHV)
	Other (3 %)		5 mil. Btu/hr (HHV)

K. Fuels Discussion:

Almost 25% of fuel used for drying operation. Gas used primarily for drying and boiler. The remainder used in boiler except for ~ 2 - 3% used for in-plant transportation.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Growth rate for malt beverages has been estimated at about 4% per year. More recent estimates are a growth rate of about double this. However, the higher figure is based on the fact that there has been a high increase in the last two years. It may be too early to determine whether the high rate will continue but it has held for the last few years. In general, the large companies are taking over the market. These companies have been building large breweries and in some cases super large industries. With approximately 24 plants of the typical size or larger in operation now, it is anticipated that in the years 1990-2000 another 10-20 plants in this size range will be constructed or expanded to this size. The cogeneration potential is good because of 24 operation and electric-steam demand.

M. Application Discussion:

N. Preferred Economic Criteria: Return on net worth ~ 13.9%.

O. Economic Discussion:

The capital expenditures range from $150-200 million per year.

P. Duty Cycle and Maintenance Philosophy:

The fermentation, ageing and refrigeration are a 24 hour a day operation. Brew house is a 2-3 shift operation for a large plant and bottling may be 2-3 shift operation. This typical plant is assumed to operate 3 shifts per day for 5 to 6 days/wk.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

24 hour electric load of about 6.040 Kw and a process steam load of 36,000 lb/hr.

Plant Name/Size: 2082 - Malt Beverages

R. Describe the level of capital investment in this industry. (1985-2000 time period)

In the year 2000 this is estimated at $300 - $400 million/yr.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

The process attached is typical of the present day operations and the 1990 time frame.

T. What is the national capacity for producing this product

Now in 1978 $50 - 60,000 \times 10^6$ lb/yr

In 2000 $90 - 110,000 \times 10^6$ lb/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

One possible change would be to do the mashing operation at a central plant. The filtered product called "wort" would be concentrated by evaporation. The concentrated wort would then be shipped to regional plants where it is reconstituted, (contd next page).

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Growth trends estimated at ~ 4%/year for the long range; however, recent estimates are about double this based on recent experience.

W. National energy consumed by this process (fossil plus elec. x 3 = total BTU/yr).

In 1978 750 x 10" BTU/yr

In 1985 1200 x 10" BTU/yr

In 2000 1900 x 10" BTU/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Typical size today and future are at 800×10^6 lb/yr and larger. Some plants up to $2,000 \times 10^6$ lb/yr.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached process flow diagram.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

~ 4%

This is a percentage of value added which does not include cost of raw material or profits but includes all other cost.

U. (Continued)

fermented, aged and bottled. This is currently being done by one European brewer, where concentrated wort is shipped to Florida. An American firm is doing this to supply markets in Hawaii and Alaska. This allows more efficient use of the brew house at the central plants and eliminates the need for a brew house and raw ingredients handling facilities at satellite plants.

APPENDIX A

Selection of Five Industrial Processes

Within the Food and Kindred Products

Sector (SIC 20)

A.1 Introduction

The purpose of this task was to recommend five specific industrial processes from the top nine (see Table AI) total annual energy consuming 4-digit industries within the food sector (SIC 20).

The top nine 4-digit industries are ordered on total annual energy consumption. The top five of this list are assessed for any significant factors which would eliminate them from consideration. The bottom four are assessed for significant factors which would increase the attractiveness of that 4-digit industry for co-generation application.

These industries were then ranked and evaluated on purchased fuels and electricity, thermal and mechanical process requirements, thermal energy profile, thermal energy requirements, stack waste heat estimates, plant operation, plant size distribution and other factors as indicated in Tables AII - XI.

A description of each of these industries, products and process flow diagrams are presented in Appendix B.

As a result of this evaluation, the following five 4-digit SIC food industries were considered for more detailed evaluation for cogeneration application:

2011	Meat Packing
2026	Fluid Milk
2046	Wet Corn Milling
2063	Beet Sugar
2082	Malt Beverages

Table AI

TOP NINE TOTAL
ANNUAL ENERGY CONSUMING 4-DIGIT
SIC INDUSTRIES IN
THE FOOD SECTOR (SIC 20)
(1974)

RANK	4 - DIGIT SIC	DESCRIPTION	TOTAL ANNUAL PURCHASED ENERGY (FOSSIL PLUS ELECTRICITY) (10^{12} BTU/YR)
1	2063	BEET SUGAR REF.	81.6
2	2046	WET CORN MILLING	78.9
3	2011	MEAT PACKING PLANTS	76.9
4	2082	MALT BEVERAGES	49.4
5	2033	CANNED FRUITS & VEG.	46.7
6	2051	BREAD, CAKE & REL. PROD.	43.5
7	2026	FLUID MILK	43.2
8	2075	SOYBEAN OIL MILLS	43.2
9	2062	CANE SUGAR REF.	37.6

Table AII

RANKING OF INDUSTRIES
BASED ON PURCHASED FUELS
AND ELECTRICITY

RANK	NATURAL GAS (10^{12} BTU/YR)	ELECTRICITY (10^{12} BTU/YR)	FOSSIL FUEL (10^{12} BTU/YR)
1	*2046	*2011	*2063
2	*2011	2026	*2046
3	*2063	2051	*2011
4	2075	*2082	*2033
5	*2033	*2046	*2082
6	*2082	2075	2075
7	2062	*2033	2051
8	2051	*2063	2062
9	2026	2062	2026

* TOP FIVE BASED ON TOTAL PURCHASED FUEL AND ELECTRICITY.

Table AIII

THERMAL AND MECHANICAL PROCESS REQUIREMENTS

ORDER	SIC	PURCHASED FOSSIL / PURCHASED ELEC.	THERMAL PROCESS REQ. / MECHANICAL REQ.
1	2063	120.7	15.5
2	2046	19.8	2.6
3	2011	4.6	3.1
4	2082	7.2	3.6
5	2033	10.7	5.7
6	2051	5.2	3.2
7	2026	3.0	2.0
8	2075	8.4	4.7
9	2062	97.9	14.4

Table AIV

THERMAL ENERGY PROFILE

PERCENT DISTRIBUTION

			TEMPERATURE RANGE	
ORDER	SIC	< 180°F	180 - 467°F	> 467°F
1	2063	12	83	5
2	2046	21	63	16
3	2011	97	1	2
4	2082	7	93	-
5	2033	36	64	-
6	2051	12	88	-
7	2026	100	-	-
8	2075	25	75	-
9	2062	14	75	11

Table AV

THERMAL ENERGY REQUIREMENTS

ORDER	SIC	TOTAL	PROCESS THERMAL REQ. (10^{12} BTU/YR) < 180°F	180 - 467°F	> 467°F
1	2063	57.4	6.9	47.6	2.9
2	2046	35.9	7.5	22.6	5.8
3	2011	47.1	45.7	0.5	0.9
4	2082	29.6	2.1	27.5	-
5	2033	30.7	11.1	19.6	-
6	2051	26.3	3.2	23.1	-
7	2026	23.3	23.3	-	-
8	2075	27.8	7.0	20.8	-
9	2062	26.3	3.7	19.7	2.9

Table AVI

THERMAL ENERGY REJECTION IN STACK

ORDER	SIC	ENERGY (10^{12} BTU/YR) < 800°	> 800°
1	2063	13.6	.7
2	2046	7.5	1.5
3	2011	11.6	.2
4	2082	7.4	-
5	2033	7.7	-
6	2051	6.3	-
7	2026	5.8	-
8	2075	7.0	-
9	2062	5.9	.7

Table AVII

INDUSTRIAL PROCESS SUMMARY

SIC	MAJOR THERMAL PROCESS			MAJOR MECHANICAL PROCESS
2011	SCALD		140°F	REFRIGERATION
	WASH		95%	
2026	PAST.		165°F	REFRIGERATION
			100°F	
2033	STERILIZATION		100%	SIZE REDUCTION:
	RETORT		< 250°	PULPING, SLICING,
	BLANCH			ETC.
2046	EVAP.	300°F	35%	MILLING
	DRYERS	1000°F	16%	
2051	BAKING		88%	MIXING
			440°F	
2062	EVAP.	265°F	75%	MIXING AND CENTRIFUGE
2063	EVAP	275°F	48%	MIXING AND CENTRIFUGE
	PULP DRYING	250°F	25%	
2075	DESOLVENTIZER	215°F	37%	SIZE REDUCTION:
	MEAL DRYER	350°F	27%	MILLING, EXTRACTING
				AND DECHILLING
2082	DRYER	400°F	58°F	REFRIGERATION
	BREWING	212°F	25°F	MIXING

Table AVIII

INDUSTRY OPERATION

ORDER	SIC	YEARLY OPERATION	SHIFTS/ DAY	HOURS/ YR.
1	2063*	SEASONAL (4 1/2 MONTHS)	3	2800
2	2046	YEAR ROUND	3	6600
3	2011	SEMI SEASONAL	1	2100
4	2082	YEAR ROUND	3	6600
5	2033	VERY SEASONAL (2 1/2 MONTHS)	2 1/2	1600
6	2051	YEAR ROUND	2	4000
7	2026	YEAR ROUND	1	2100
8	2075	YEAR ROUND	1	2100
9	2062	YEAR ROUND	3	6600

* THERE IS A SEASONAL COMPONENT WITH 2 8 0 0 HRS. - AND A REFINING COMPONENT THAT IS ANNUAL - 6 6 0 0 HRS.

Table AIX

PLANT SIZE AND ENERGY

DISTRIBUTION PROFILE*

SIC	< 20	21 - 100	> 100	TOTAL
2011	1611 (5%)	570 (16%)	294 (79%)	2475
2026	1220 (7%)	914 (39%)	373 (54%)	2507
2033	417 (3%)	343 (19%)	278 (78%)	1038
2046	14 (1%)	10 (12%)	17 (87%)	41
2051	1944 (1%)	766 (2%)	613 (97%)	3323
2062	5 (1%)	9 (5%)	19 (94%)	33
2063	7 (1%)	1 (1%)	53 (98%)	61
2075	20 (1%)	45 (28%)	29 (71%)	94
2082	37 (1%)	35 (4%)	95 (95%)	167

* NUMBER OF EMPLOYEES	SIZE
< 20	SMALL
21 - 100	MEDIUM
> 100	LARGE

(%) PERCENT OF TOTAL ENERGY CONSUMED IN PLANT SIZE CATEGORY.

Table AX

PERTINENT COMMENTS REGARDING COGENERATION OPTIONS

- *PLANT TRENDS*: IN GENERAL THERE IS A TREND TO LARGER, MORE INTEGRATED PLANTS ACROSS ALL SECTORS - SIC 2051 (BAKING) IS AN EXCEPTION - THE TREND HERE IS TO SMALLER RETAIL UNITS. IN GENERAL FOR NEW CAPACITY THE TREND IS TO EXPANSION OF EXISTING FACILITIES RATHER THAN ENTIRELY NEW PLANTS.

- *PRODUCT CHANGES*: TRENDS IN PACKAGING REPRESENTS GREATEST AREA FOR POTENTIAL PRODUCT EVALUATION. LIFESTYLE PATTERNS - REDUCED MEAT AND SUGAR CONSUMPTION WILL LIKELY HAVE THE LARGEST IMPACT ON SHIFTS BETWEEN PRODUCTS.

- *TECHNOLOGY TRENDS* - GENERALLY STABLE PROCESS USE, EXCEPT FOR SPECIFIC COMMENTS:

  - 2026 - SHIFT TO STERILE CONTAINERS WHICH REQUIRE AN INCREASE IN PROCESSING TEMPERATURE FROM 165 TO 265°F.

  - 2033 - POSSIBLE USE OF STERILE PLASTIC CONTAINERS TO REPLACE CANS - LESS ENERGY USE. IN GENERAL TRENDS OVER THE LAST TEN YEARS HAVE BEEN TOWARD DECREASE IN PROCESSING TIME IN ALL PHASES OF OPERATION.

Table AX (Cont.)

- *FINANCIAL CONSIDERATIONS*: IN GENERAL A DCF OF 15-20% IS REQUIRED OR A COMPLEX PAYBACK OF 2 1/2 - 5 YEARS. THE TWO SECTORS WITH NARROWEST PROFIT MARGIN ARE 2033 AND 2011. IN GENERAL, INCREASE IN PRODUCT QUALITY, CAPACITY OR NEW PRODUCTS HAVE THE HIGHEST PRIORITY FOR CAPITAL IMPROVEMENT FUNDS.

- *FUEL PREFERENCE*: ONLY IN 2051 (BAKING) IS NATURAL GAS REQUIRED AS A CLEAN FUEL. IN OTHER SECTORS THE FOSSIL REQUIREMENT IS AS A BOILER FUEL.

- *HISTORY OF CO-GENERATION* - 20 TO 30 YEARS AGO THERE WAS SOME PRODUCTION OF BY-PRODUCT POWER - THIS HAS NOW ALL BUT DISAPPEARED. NO ONE SECTOR SEEMED FAVORED.

- *SPECIAL ENVIRONMENTAL OR LEGAL CONSIDERATIONS* - THERE APPEARS TO BE NO SPECIAL CONSIDERATIONS THAT WOULD HAMPER COGENERATION IN ANY OF THE SECTORS.

Table AXI

S E L E C T I O N   P R O C E S S

1. BASIC APPROACH IS TO CONSIDER TOP 5 ENERGY USERS - TO ADD OR SUBTRACT FROM THESE BASED ON THE FOLLOWING CONSIDERATIONS:

   - H O U R S   O F   O P E R A T I O N
   - P L A N T   S I Z E   D I S T R I B U T I O N
   - T E M P E R A T U R E   R E Q U I R E M E N T S
   - T H E R M A L / M E C H A N I C A L
   - " O T H E R S " - F I N A N C I A L, E N V I R O N M E N T A L N E W   T E C H N O L O G Y,   P R O D U C T   T R E N D S, H I S T O R I C A L   I N C L I N A T I O N, E T C.

2. - ALL SECTORS APPEAR TO HAVE SIGNIFICANT LOW TEMPERATURE REQUIREMENTS (< 4 6 7 °)
   - ALL SECTORS TILT TOWARD LARGE PLANTS - EXCEPT 2 0 5 1 (BAKING).
   - A WIDE RANGE OF THERMAL/MECHANICAL RATIOS OCCUR - THE RELEVANCE OF THIS DEPENDS ON THE COGENERATION OPTION.
   - AMONG THE "OTHER" FACTORS THERE APPEAR TO BE NO DECISIVE CONSIDERATION THAT ARISES HERE.
   - THE MAJOR FACTOR USED IS THEN HOURS OF OPERATION OR SEASONAL PERFORMANCE.

Table AXI (Cont.)

- SIC 2 0 3 3 IS ELIMINATED AS BEING MOST SEASONAL - THE OTHERS IN THE TOP FIVE LIST ARE RETAINED.

- AMONG THE BOTTOM FOUR SIC 2 0 5 1 IS ELIMINATED BASED ON A TREND TO SMALLER PRODUCTION UNITS. SIC 2 0 6 2 IS ELIMINATED BASED ON ITS SIMILARITY TO SIC 2 0 6 3 WHICH HAS BEEN INCLUDED. THIS LEAVES SIC 2 0 7 5 AND SIC 2 0 2 6 FOR CONSIDERATION. OF THESE SIC 2 0 2 6 HAS BEEN CHOSEN AS A STABLE, YEAR ROUND PRODUCT WITH LARGE THERMAL DEMAND UNDER 1 8 0°F.

APPENDIX B

Industrial Process and Product Description of Initial Nine Industries Within the Food Sector

Table BI

2011 Meat Packing Plants

Establishments primarily engaged in the slaughtering, for their own account or on a contract basis for the trade, of cattle, hogs, sheep, lambs, and calves for meat to be sold or to be used on the same premises in canning and curing, and in making sausage, lard, and other products. Establishments primarily engaged in killing, dressing, and packing poultry, rabbits, and other small game are classified in Industry 2016; and those primarily engaged in killing and processing horses and other nonfood animals are classified in Industry 2047. Establishments primarily engaged in manufacturing sausages and meat specialties from purchased meats are classified in Industry 2013; and establishments primarily engaged in canning meat for baby food are classified in Industry 2032.

Abattoirs, on own account or for the trade: except nonfood animals
Bacon, slab and sliced: *mitse*
Beef, *mitse*
Blood meal
Canned meats, except baby foods: *mitse*
Cured meats, *mitse*
Hams and picnics, *mitse*
Hides, cured or uncured: *mitse*
Lamb, *mitse*
Lard, *mitse*
Meat extracts, *mitse*
Meat, *mitse*
Meat packing plants
Mutton, *mitse*
Pork, *mitse*
Sausages, *mitse*
Slaughtering plants: except nonfood animals
Variety meats (fresh edible organs), *mitse*
Veal, *mitse*

2026 Fluid Milk

Establishments primarily engaged in processing (pasteurizing, homogenizing, vitaminizing, bottling) and distributing fluid milk and cream, and related products; including cottage cheese.

Buttermilk, cultured
Chocolate milk
Cottage cheese, including pot, bakers', and farmers' cheese
Cream, aerated
Cream, bottled
Cream, plastic
Cream, sour
Flavored milk drinks
Kumyss
Milk, acidophilus
Milk, bottled
Milk processing (pasteurizing, homogenizing, bottling) and distribution
Milk products, made from fresh skim milk
Whipped cream
Whipped topping, butterfat base
Yoghurt
Zoolak

2033 Canned Fruits, Vegetables, Preserves, Jams, and Jellies

Establishments primarily engaged in canning fruits and vegetables, and fruit and vegetable juices; and in manufacturing catsup and similar tomato sauces, preserves, jams, and jellies. Establishments primarily engaged in canning seafoods (except frozen) are classified in Industry 2091; and canned specialties, baby foods and soups (except seafood) in Industry 2032.

Artichokes in olive oil, bottled
Barbecue sauce
Catsup
Cherries, maraschino
Chili sauce, tomato
Fruit butters
Fruits: canned, bottled, and preserved
Hominy, canned
Jams
Jellies, edible
Juices, fruit and vegetable: canned, bottled, and bulk
Ketchup
Kraut, canned
Marmalade
Mushrooms, canned
Nectars, fruit
Olives, including stuffed: bottled
Pastes, fruit and vegetable
Preserves
Purees, fruit and vegetable
Sauerkraut, canned
Seasonings (prepared sauces), tomato
Tomato juice and cocktails, bottled and canned
Tomato paste
Tomato sauce
Vegetables, canned

2046 Wet Corn Milling

Establishments primarily engaged in milling corn or sorghum grain (milo) by the wet process, and producing starch, sirup, oil, sugar, and byproducts, such as gluten feed and meal. Establishments primarily engaged in manufacturing starch from other vegetable sources (potato, wheat, etc.) are also included. Establishments primarily engaged in manufacturing table sirups from corn sirup and other ingredients, and those manufacturing starch base dessert powders, are classified in Industry 2099.

Corn oil cake and meal
Corn sirup, dried
Corn starch
Dextrine
Dextrose
Feed, gluten
Hydrol
Meal, gluten
Oil, corn: crude and refined
Potato starch
Rice starch
Sirup, corn: unmixed
Starch, instant
Starch, liquid
Starches, edible and industrial
Steepwater concentrate
Sugar, corn
Tapioca
Wheat starch

Table BI (Cont.)

2051 Bread and Other Bakery Products, Except Cookies and Crackers

Establishments primarily engaged in manufacturing bread, cakes, and other "perishable" bakery products. Establishments manufacturing bakery products for sale primarily for home service delivery, or through one or more non-baking retail outlets, are included in this industry. Establishments primarily engaged in producing "dry" bakery products, such as biscuits, crackers, and cookies are classified in Industry 2052. Establishments producing bakery products primarily for direct sale on the premises to household consumers are classified in Retail Trade, Industry 5462.

Bagels
Bakeries, manufacturing for home service delivery
Bakery products, "perishable": bread, cakes, doughnuts, pastries, etc.
Biscuits, baked: baking powder and raised
Bread, brown: Boston and other—canned
Buns (bakery products)
Charlotte Russe (bakery product)
Bakeries: wholesale, wholesale and retail combined
Bakery products, partially cooked (not frozen)
Crullers
Knishes
Pastries: Danish, French, etc.
Pies, except meat pies
Rolls (bakery products)
Sponge goods (bakery products)
Sweet yeast goods

2062 Cane Sugar Refining

Establishments primarily engaged in refining purchased raw cane sugar and sugar sirup.

Cane sugar, refined: made from purchased raw cane sugar or sugar sirup
Granulated cane sugar, made in refineries from purchased sugar
Refineries, cane sugar
Refiners' blackstrap molasses
Refiners' sirup, cane
Sirup, cane: made in sugar refineries from purchased sugar
Sugar, invert

2063 Beet Sugar

Establishments primarily engaged in manufacturing sugar from sugar beets.

Dried beet pulp
Liquid sugar or sirup, beet sugar refining
Molasses, made from sugar beets
Sugar, beet

2075 Soybean Oil Mills

Establishments primarily engaged in manufacturing soybean oil, and byproduct cake and meal. Establishments primarily engaged in refining soybean oil into edible cooking oils are classified in Industry 2079.

Lecithin
Soybean oil, cake, and meal

2082 Malt Beverages

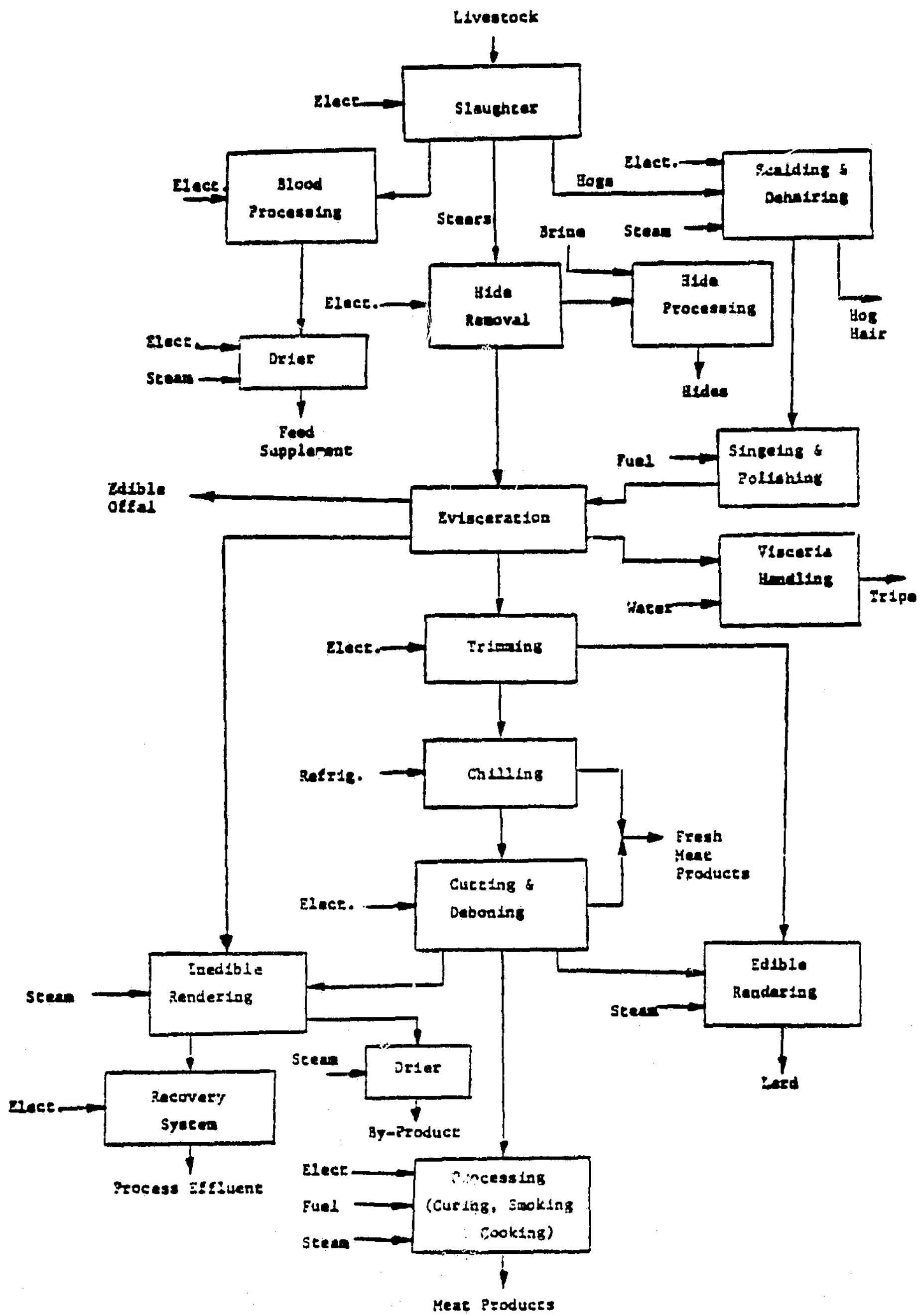
Establishments primarily engaged in manufacturing all kinds of malt beverages. Establishments primarily engaged in bottling purchased malt beverages are classified in Industry 5181.

Ale
Beer (alcoholic beverage)
Breweries
Brewers' grain
Liquors, malt
Malt extract, liquors, and sirups
Near beer
Porter (alcoholic beverage)
Stout (alcoholic beverage)

Process Flow Diagrams

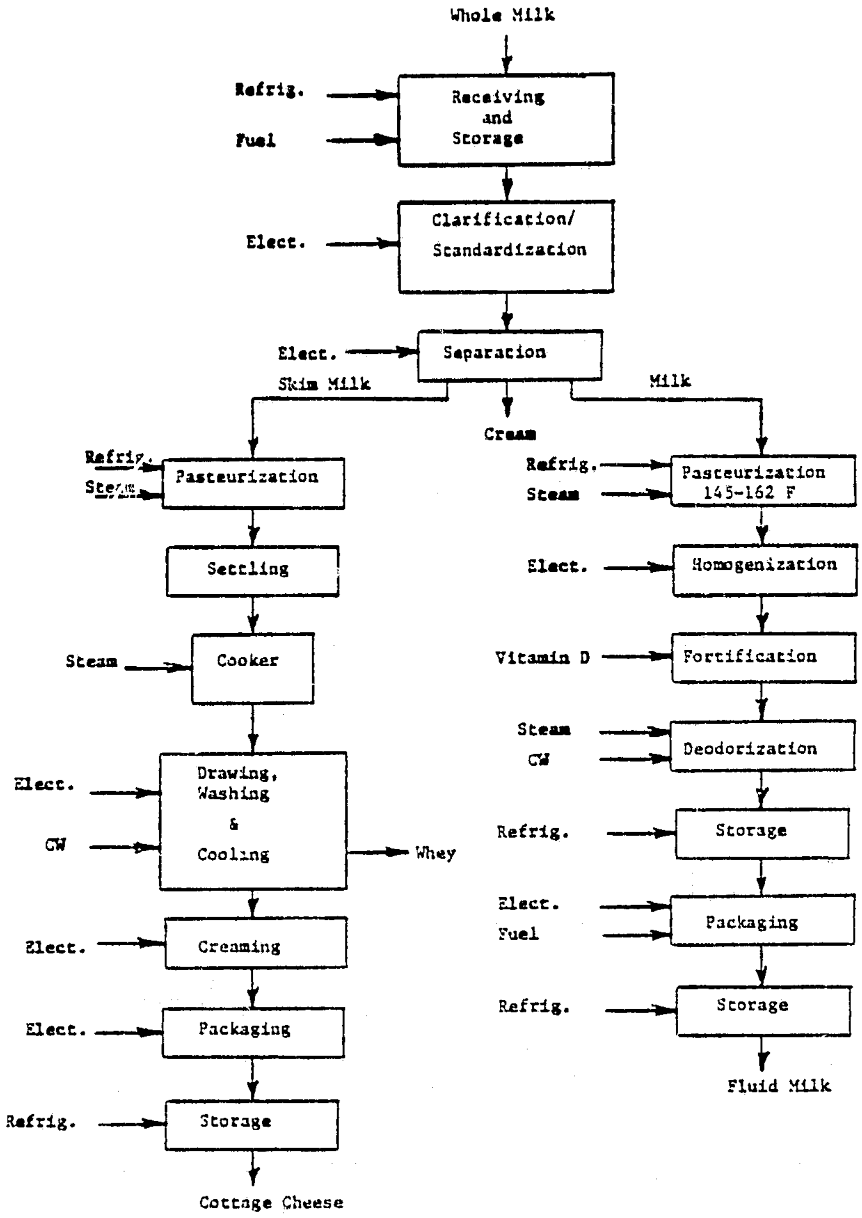
2011 - MEAT PACKING PLANTS

PROCESS FLOW



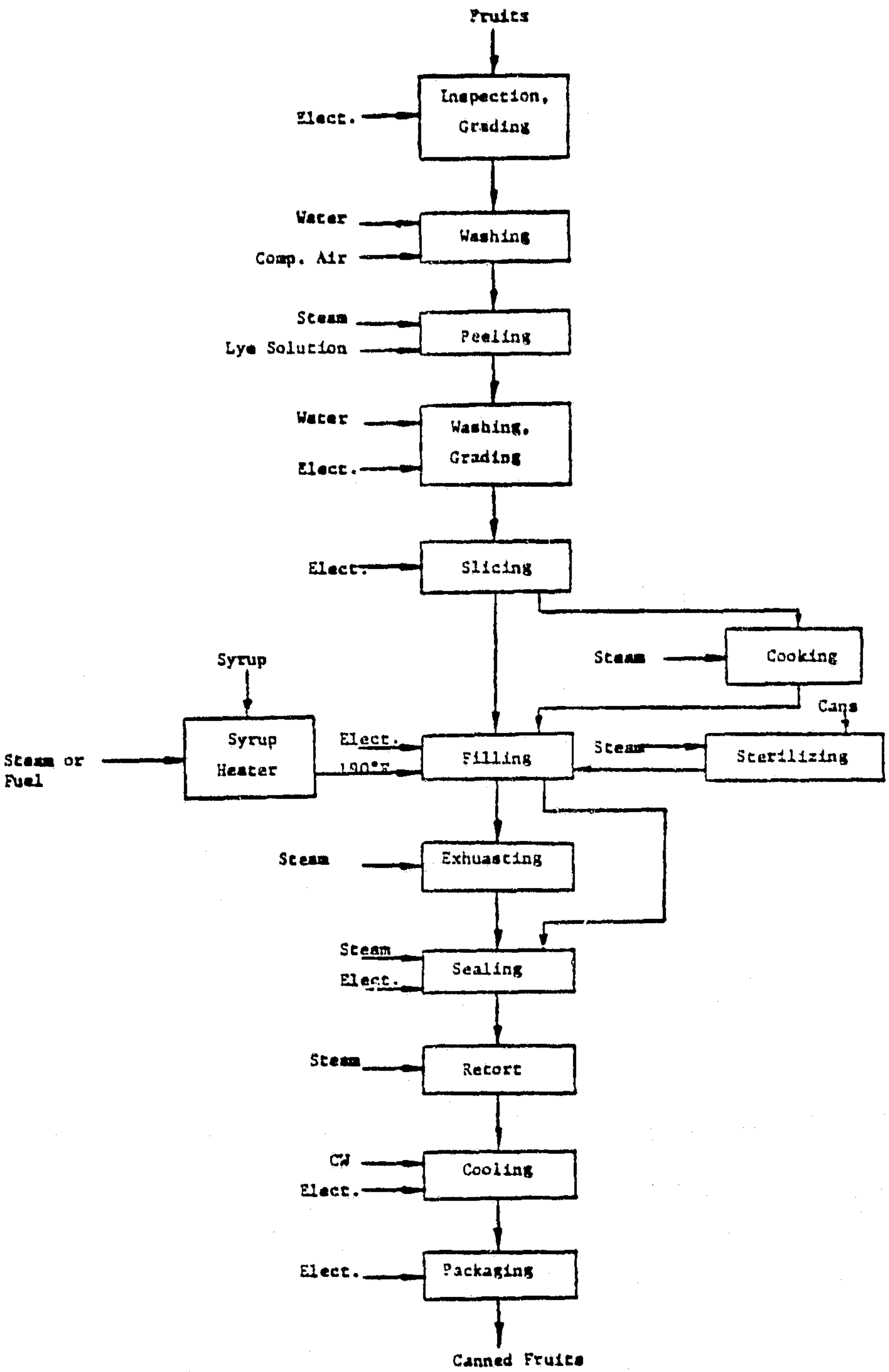
2026 - FLUID MILK

PROCESS FLOW



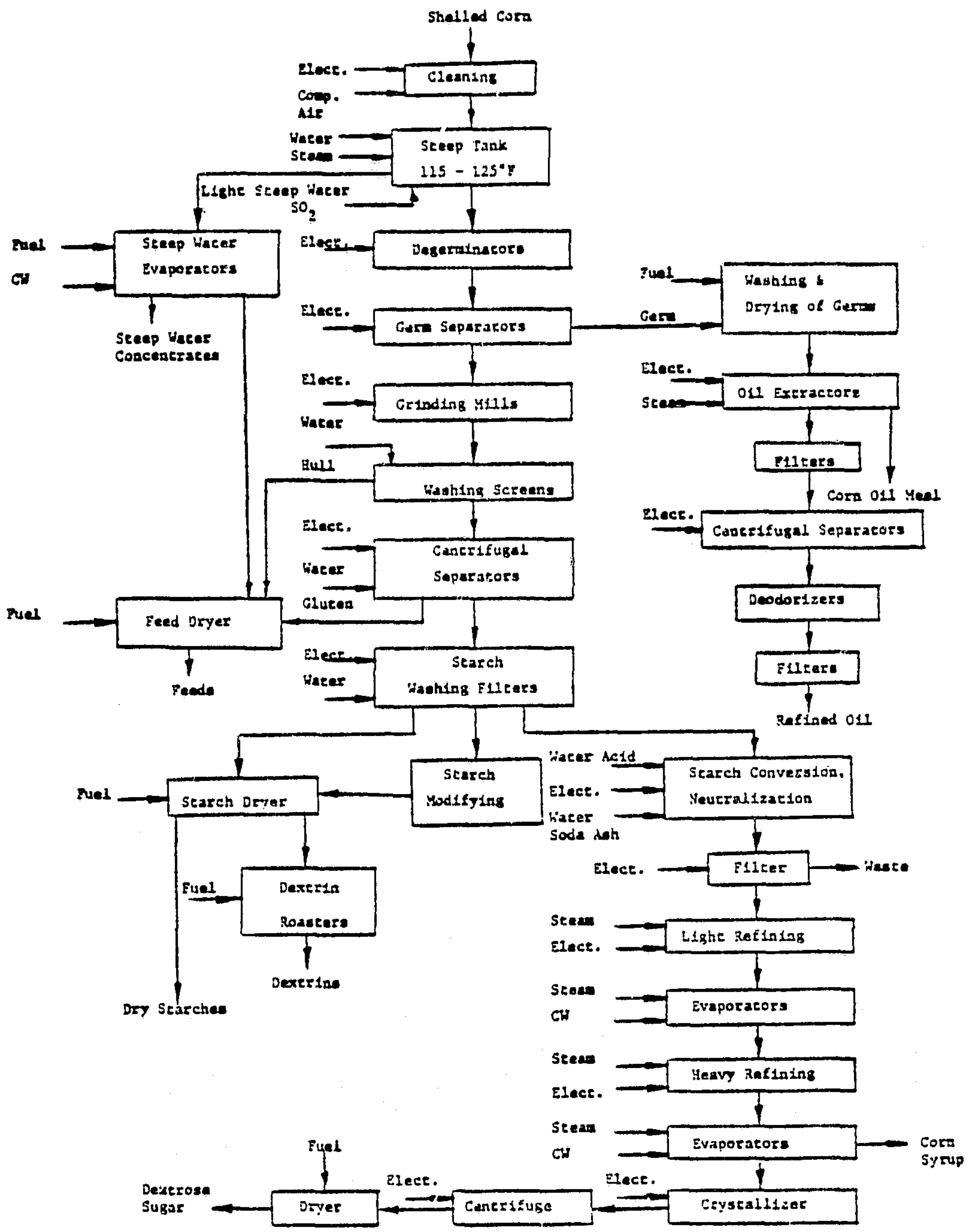
2033 - CANNED FRUITS AND VEGETABLES

PROCESS FLOW



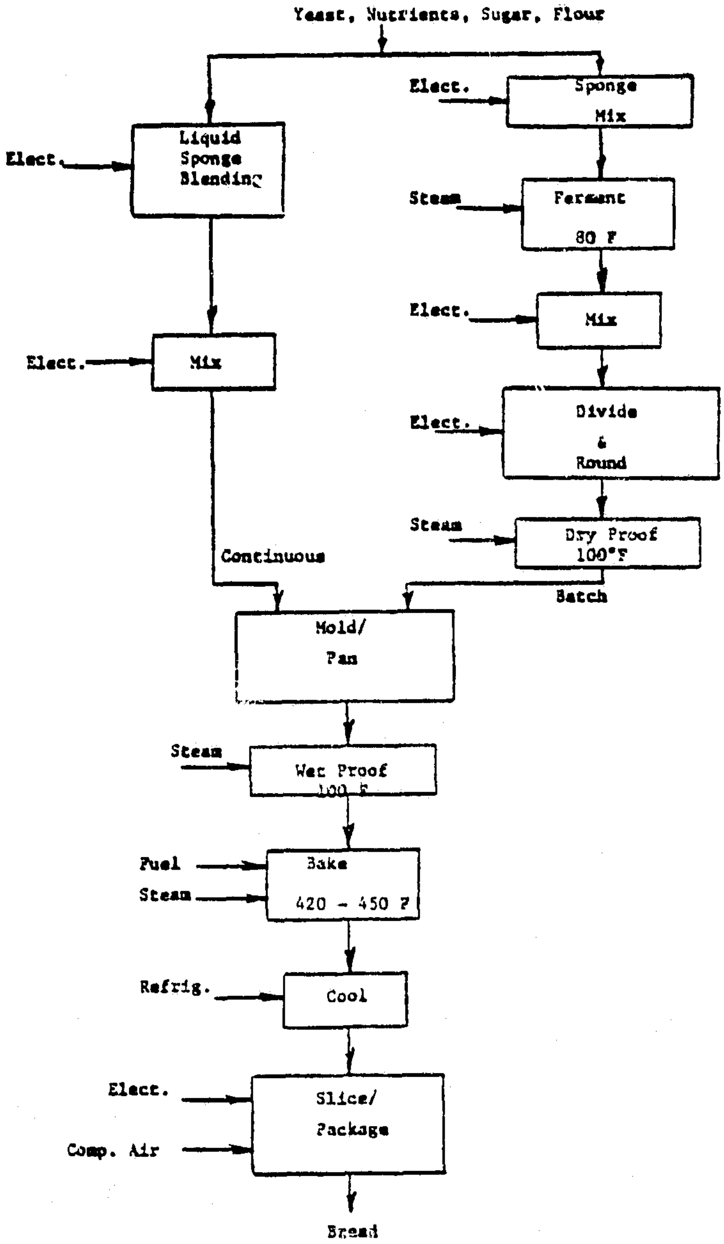
2046 - WET CORN MILLING

PROCESS FLOW



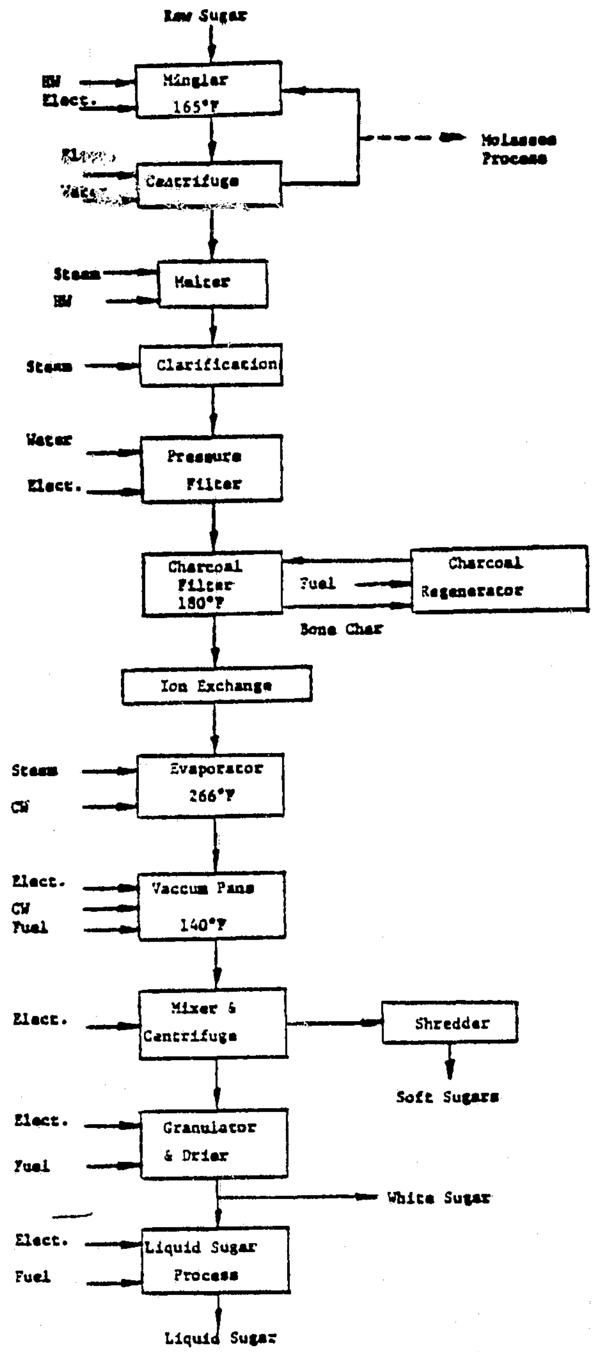
2051 - BREAD, CAKE AND RELATED PRODUCTS

PROCESS FLOW



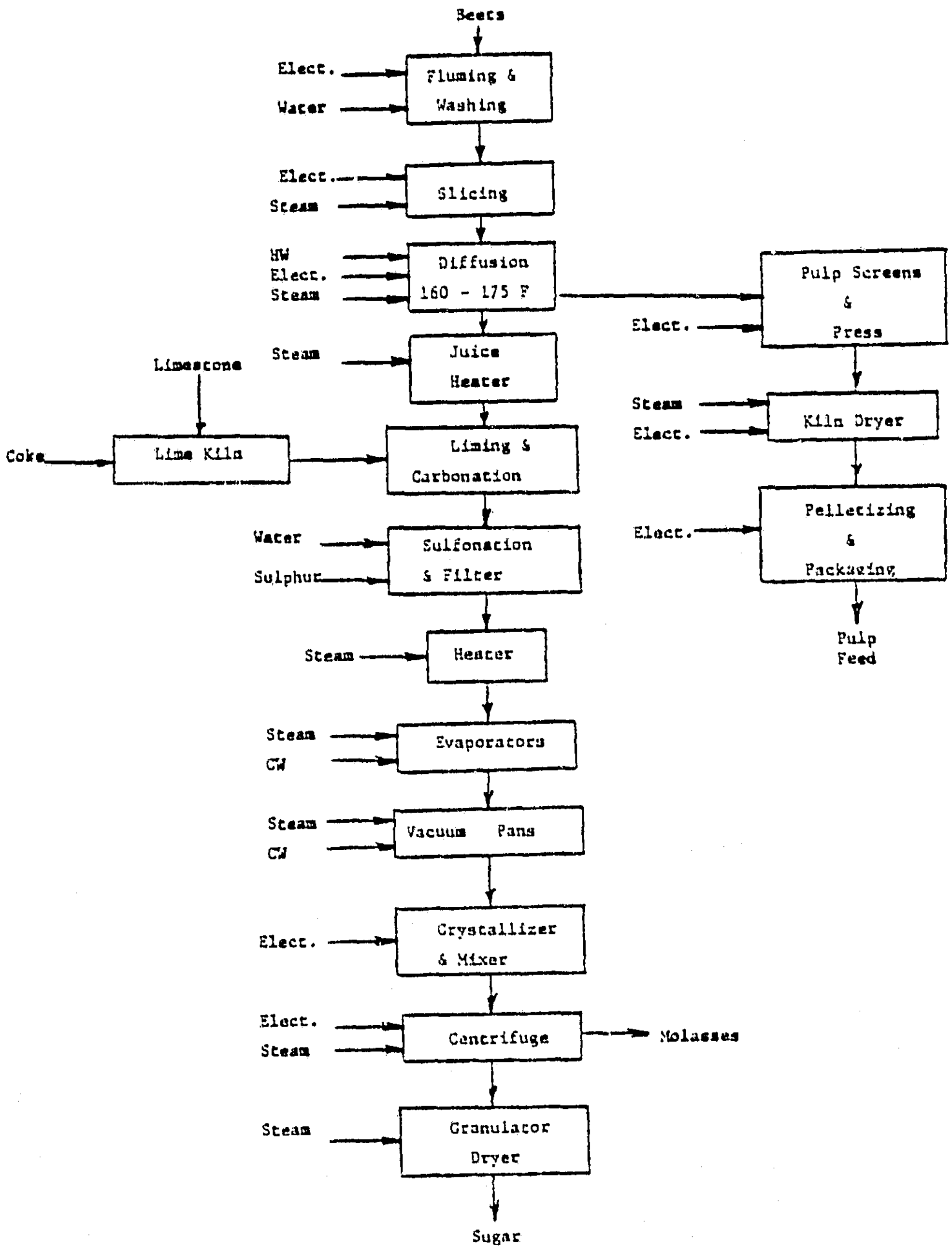
2062 - CANE SUGAR REFINING

PROCESS FLOW



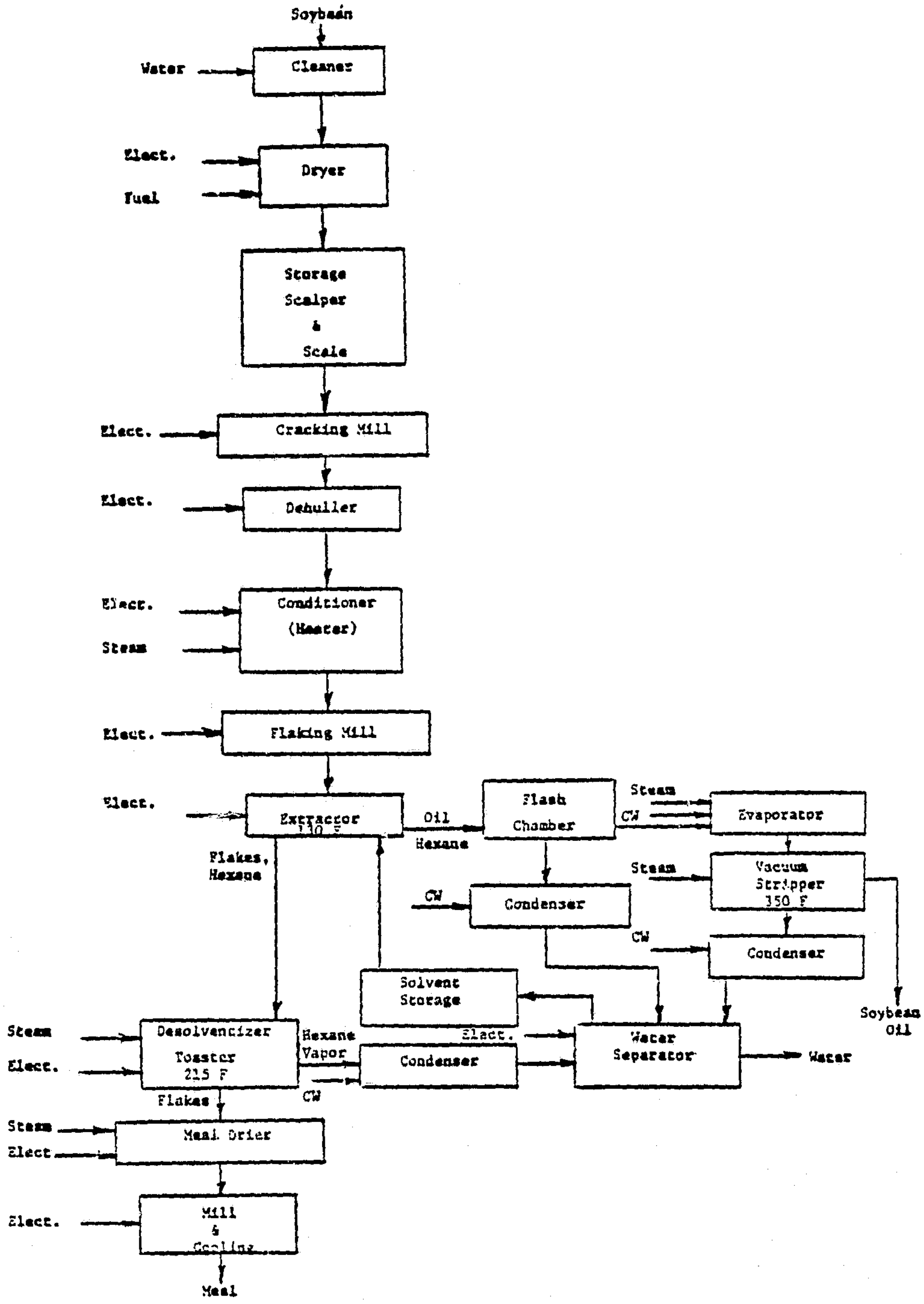
2063 - BEET SUGAR

PROCESS FLOW



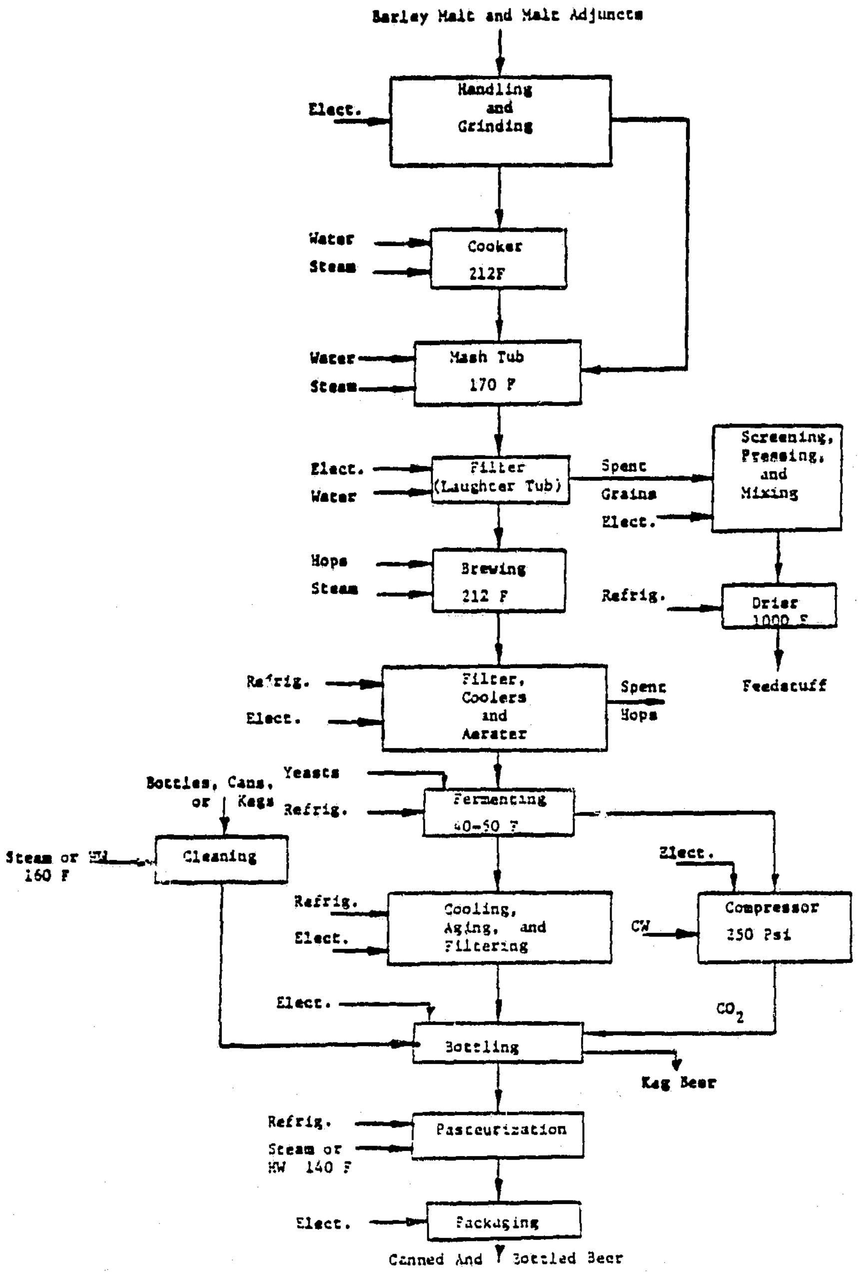
2075 - SOYBEAN OIL MILLS

PROCESS FLOW



2082 - MALT BEVERAGES

PROCESS FLOW



APPENDIX C

CTAS PLANT DATA SHEETS

for Five Selected Industries:

2011 - Meat Packing

2026 - Fluid Milk

2046 - Wet Corn Milling

2063 - Beet Sugar Refining

2082 - Malt Beverages

CTAS Plant Data Sheet

A. Plant Name/Size: 2011-Meat Packing (Typical of the 100-500 employee range representing 34% of energy of 2011)

B. Products:

Product	lb/yr, etc.
Meat Products	48×10^6
Lard & Tallow	1.3×10^6
Hide	3.8×10^6

C. Plant Kilowatt Requirements: Average 1940 kW; Peak 2330 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
24×10^3	@	15 ,	25% of steam condensate ,	180°F
	@	,	,	
	@	,	,	

E. Other Heat to Process (Describe):
Hot water @ 140°-180° assumed made from 40% of the 15 psig steam. Singeing and smoking, cooking and curing require approximately 2×10^6 BTU/hr.

F. Plant Hours of Operation at Average Conditions: 2100 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Refrig. Comp.	320	380	-	-	electric

H. Operational Considerations:
Slaughtering operation is usually a one shift operation. However, carcasses are chilled overnight and storage areas are refrigerated. Refrigeration load is 24 hours per day. Industry is semi-seasonal. They run at full capacity in the Fall and Winter. During late Spring and Summer, fewer animals are availalbe and some plants will operate only a few days per week.

I. Waste Heat Streams:

lb/hr	Temp.	Description
118,000	400-500°F	Stack from boiler
320	200-220°F	Vapor from blood dryer
7,000	400-550°F	Stack from singeing
34,000	200°F	Vapor from inedible rendering dryer
21,000	400-550°F	Stack from smoking & cooking

CTAS Plant Data Sheet

(Typical of the 100-500 employee range representing 34% of energy of 2011)

Plant Name/Size: 2011-Meat Packing -

		National % Distribution		Using Same Distribution for Typical Plant.	
J. Fuels:	Primary Fuel	Gas	/ (64.3%)	27.4	mil. Btu/hr (HHV)
	Secondary Fuel	Other	/ (14.5%)	6.2	mil. Btu/hr (HHV)
	By-product Fuel	Coal	/ (11.6%)	4.9	mil. Btu/hr (HHV)
		Oil	(9.6%)	4.1	" " "

K. Fuels Discussion:

90% of fuel used to generate steam or hot water. The remainder for singeing, smoking, or vehicle transportation. This 10% generally requires special fuels, but again this is a small fraction of total.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Approximately 295 plants of this size or larger in the country now. Although growth rate has been predicted at over 11%/yr, this may not show up as a significant increase in number of plants. There appears to be a surplus of slaughtering capacity in the industry.

M. Application Discussion:
Since World War II, the trend has been for movement of plants from large central slaughtering areas (e.g. Chicago) to areas near where animals are grown. Thus modernization of large plants in animal production areas and building of an estimated 20-40 plants by year 2000 of this typical size due to expansion of smaller plants and new construction. Cogeneration potential good because of electrical use for refrigeration and large steam hot water requirements.

N. Preferred Economic Criteria: Estimated criteria of over 8% return on net worth.

O. Economic Discussion:

Capital expenditures for equipment and new structures range from $150-250 million per year.

P. Duty Cycle and Maintenance Philosophy:

Refrigeration operates on 24 hour cycle while basic plant operations are on 1 shift/day.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

For typical plant discussed here, average electrical load from 8 am to 4 pm is 1940 Kw and from 4 pm to 8 am the average load is 240 Kw. The steam rate of 24,000 lb/hr is relatively constant from 8 am to 4 pm as are the waste streams.

CTAS Plant Data Sheet

Plant Name/Size: 2011-Meat Packing

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Estimated at $200-400 million/yr.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
The attached flow sheet is typical for most plants and probably will not change in the future.

T. What is the national capacity for producing this product

Now in 1978 Estimated 35,000 x 10^6 lb/yr (Production assumed to be ~ 70% of capacity)

In 2000 40-50,000 x 10^6 lb/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.
Major factors may be substitution for natural gas in boilers to maintain production and also the eating habits of public - if there is reduction in diet of red meats.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)
Increased consumption has been projected at over 11%/yr but may be better correlated with GNP or disposable income. However, this may be over stated due to change in diet of public.

W. National energy consumed by this process (fossil and elec. x 3 = total BTU/yr)

In 1978 117 x 10^{12} BTU/yr

In 1985 132 x 10^{12} BTU/yr

In 2000 191 x 10^{12} BTU/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.
Size of plant described is typical of 100-500 employee range (30-80 x 10^6 lb/yr production) which appears to be typical of the future.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See attached Process Flow Diagram and Summary Sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

5.5%

This is a percentage of value added which does not include cost of raw materials or profits but all other costs.

CTAS Plant Data Sheet

A. Plant Name/Size: 2026-Fluid Milk - Typical plant of the 50-250 employee range representing 63% of energy consumed in 2026. Typical plant production at 48 x 10^6 lb/yr of product.

B. Products:

Product	lb/yr, etc.
Fluid Milk	35 x 10^6
Cottage Cheese	13 x 10^6

C. Plant Kilowatt Requirements: Average 1310 kW; Peak 1570 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
11,000	@	15	50%	180°
	@			
	@			

E. Other Heat to Process (Describe):

Hot water produced from steam in the 160°F range.

F. Plant Hours of Operation at Average Conditions: 2100 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
No single large motor or drives.				

H. Operational Considerations:

Not all plants will make cottage cheese. However, some plants will make quite a variety of products including cottage cheese, ice cream, etc. Fluid milk operations are generally one shift per day, five days per week. They are year round operations.

I. Waste Heat Streams:

lb/hr	Temp.	Description
10,000	120-150°F	Waste water
37,000	400-500°F	Boiler stack

CTAS Plant Data Sheet

Plant Name/Size: 2026- Fluid Milk

		National % Distribution		Using Same Distribution for Typical Plant	
J. Fuels:	Primary Fuel	Gas	/ (42%)	6.0	mil. Btu/hr (HHV)
	Secondary Fuel	Other Oil	/ (39%) (18%)	5.6 2.6	mil. Btu/hr (HHV)
	By-product Fuel	Coal	/ (1%)	.1	mil. Btu/hr (HHV)

K. Fuels Discussion:

Fuels used predominantly for steam production. Other type fuels used such as gas, propane, etc. used for vehicles and in most cases fuels not classified by Census of Mfg. but are used for steam production.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Per capita consumption of fluid milk is fairly constant and therefore total consumption will vary with the population. Projections are for 1.5 to 1.7% growth rate per year. Construction of new plants in the dairy industry in the past vew years appears to be mainly for plants for other dairy products (cheese, etc.). The trend in the industry

M. Application Discussion:

is for closing of smaller local plants and upgrading of remaining plants. The plants that are closed are small enough that they don't significantly affect industry capacity. Approximately 735 plants of this typical size or larger are in the country now. Expansion of present small plants, increasing capacity and construction of new plants of this size may represent an additional 20 to 50 new plants by the year 2000. The cogeneration potential is good because of low presure steam and hot water requirements along with the electric requirements. However, payback is a strong function of the single shift operation.

N. Preferred Economic Criteria: Return on net worth of 11.4%.

O. Economic Discussion:

Capital expenditures for equipment and new structures range from $125 to 175 million per year.

P. Duty Cycle and Maintenance Philosophy:

A fraction of the refrigeration operates on a 24 hour cycle. Cleaning operation significant at end of day period and at start up.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

Approximately 50 Kw load on a 24 hour basis and the remainder 1260 Kw during the eight hour shift. The steam and waste stream profiles are relatively level for eight hours.

CTAS Plant Data Sheet

Plant Name/Size: 2026 - Fluid Milk

R. Describe the level of capital investment in this industry. (1985-2000 time period)
In the year 2000, it is estimated that the capital expenditure will range from $200 to $300 million per year.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
The attached flow sheet is fairly typical, although not all plants will make cottage cheese, etc. The process will stay basically the same for some time to come.

T. What is the national capacity for producing this product

Now in 1978 60-70,000 x 10^6 lb/yr.

In 2000 80-90,000 x 10^6 lb/yr.

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.
Any major changes would be created by form of milk products. Such as dry milk, etc. and therefore packaging may change. Possible shift to sterile containers which require a slight increase in temperatures to 260°-270°F but no rapid changes predicted.

Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)
Per capita consumption of fluid milk is fairly constant and therefore total consumption will vary with the population. Projections are for a 1.7% growth rate.

W. National energy consumed by this process (fossil plus elec. x 3 = total BTU/yr)

In 1978 71 x 10^{12} BTU/yr

In 1985 80 x 10^{12} BTU/yr

In 2000 101 x 10^{12} BTU/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.
The size of the plant described here is typical of the 50-250 employee range (40-60 x 10^6 lb/yr per plant) which appears to be typical of plants of the future and also represents the size range consuming the largest fraction of energy.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See attached Process Flow Diagram and Summary Sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.
5%
This is a percentage of value added which does not include cost of raw material or profits but includes all other costs.

CTAS Plant Data Sheet

A. Plant Name/Size: 2046-Wet Corn Milling, 84% of energy in plants with 500 or greater employees.

B. Products:

Product	lb/yr, etc.
Corn Oil	1.4×10^9 lb/yr of corn processed
Corn Oil Meal	
Corn Syrup	

C. Plant Kilowatt Requirements: Average 28.5 MW; Peak 35.6 MW;
(Of this approx. 57% is self generated - national avg.)

D. Steam Requirements (Process & Heating):

	lb/hr	@	psig,	Returns %,	Temp. of Returns
Process	41.9×10^4	@	15	47% of steam cond. returned	180°F
Heating	3.8×10^4		15		
Cleanup	20.2×10^4	@	15		
On-Site Generation	10.5×10^4	@	500		

E. Other Heat to Process (Describe):

There are significant direct heat requirements in the drying and roasting operations (see process flow sheets)

Feed Dryer - 10.5×10^7 Btu/hr

Dextrin Roaster 2.9×10^7 Btu/hr

Overall, the ratio of steam required to direct heat is 4.8.

F. Plant Hours of Operation at Average Conditions: 6600 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Approx. 9 distinct large hp loads all about the same hp. (see process flow sheets)	1850 HP				Electric Motors

H. Operational Considerations:

There is very large self generation in this industry - as a national average 57% of electrical requirement is self generated - it is assumed here that 57% plant requirements are self generated.

I. Waste Heat Streams: There is some additional waste heat in cooling water (95-110°F) and moist air (200°F) from dryers - these have not been included due to inaccessibilty of recovery.

	lb/hr	Temp.	Description
(gaseous)	10^5	400°F	Feed Dryer Stack
(gaseous)	3×10^5	450°F	Electric Generation
(gaseous)	25×10^5	450°F	Boiler Stack
(liq.)	4×10^5	180°F	Non Returned Condensate

CTAS Plant Data Sheet

Plant Name/Size: 2046-Wet Corn Milling, 84% of energy in plants with 500 or greater employees.

National Fuel Distribution (%) — Typical Plant Size Distribution

J. Fuels:

	Fuel	National Fuel Distribution (%)	Typical Plant Size Distribution	
Primary Fuel	Nat. Gas	(57%)	740	mil. Btu/hr (HHV)
Secondary Fuel	Coal Oil	(32%) (8%)	415 120	mil. Btu/hr (HHV)
By-product Fuel	Other	(1.5 %)	20	mil. Btu/hr (HHV)

K. Fuels Discussion:

Natural gas is used in the direct heat, drying and roasting operations and as boiler fuel. The other fuels are exclusively boiler fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Approx. 9 large plants now account for 84% of energy use. Growth rate is projected at 8.5% for 1978 as corn syrup production increases. With new capacity installed for corn syrup production, production should revert to the historical averages - e.g. 2/3 of GNP increase. On this basis, and the fact the new large plants are smaller than existing ones (see below) 15 large plants estimated for 1990.

M. Application Discussion:

While large plants continue to be most significant, with present capacity averaging 85,000 bushels/day - new plants (while still large) now average 35,000 bushels/day. This and the projected growth rates give rise to the number of large plants estimated above for 1990. Most new plants make corn syrup - this is not true of all older plants this is not however a high energy process. There is excellent cogeneration potential because of 24 hour operation.

N. Preferred Economic Criteria: Estimated criteria of over 9% return on net worth.

O. Economic Discussion:

Estimated capital expenditures range from $50 - 100/yr for the 1977-1979 time frame.

P. Duty Cycle and Maintenance Philosophy:

Most of the operations in the plant are 24 hours per day. With new separation techniques it may be possible in the future to do all separations in one shift and store.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

For a typical plant the average electrical load is fairly constant at 28.5 MW for 24 hrs./day. The total steam rate is also fairly constant at 65,000 #/hr. At 5600 hr/yr of operation - the plants operate at 5-6 days per week.

CTAS Plant Data Sheet

Plant Name/Size: 2046-Wet Corn Milling, 84% of energy in plants with 500 or greater employees.

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Est. $85-150 million/yr.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Process is unchanged.

T. What is the national capacity for producing this product

Now in 1978 1.7×10^{10} Lb/yr.

In 2000 3.9×10^{10} Lb/yr.

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Most new plants now make corn syrup as an additional product - this additional step is not energy intensive. No other changes are anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Historically the product grew at 2/3 GNP, however since corn syrup capacity has been added growth rate has been higher than this - it is anticipated that by 1990, 2/3 GNP growth will return.

W. National energy consumed by this process

In 1978 10.4×10^{13} BTU/yr.

In 1985 14.1×10^{13} BTU/yr.

In 2000 15.9×10^{13} BTU/yr.

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Present plant sizes for large plants (greater than 500 employees) is 85,000 bushels/day This will decrease to 35,000 bushels/day.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached Process Flow Diagram and Summary Sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

12%

This is a percentage of value added which does not include cost of raw materials or profits but does include all other costs. Numbers are from 1972 census with correction to 1978.

CTAS Plant Data Sheet

A. Plant Name/Size: 2063- Beet Sugar, Typical plant in 100-500 employee range which accounts for 86% of energy.

B. Products:

Product	lb/yr, etc.
Beet Sugar	200×10^6 Lb/yr.

C. Plant Kilowatt Requirements: Average 4700 kW; Peak 5800 kW

D. Steam Requirements (Process & Heating):

	lb/hr	@	psig,	Returns %,	Temp. of Returns
Process Steam	26×10^4	@	15		
Clean Up	2.9×10^4	@	15	62%	180°F
Space Ht.	1.2×10^4	@	15	returned	
Self Generation	2.2×10^4		500		

E. Other Heat to Process (Describe):

There are two significant direct heat requirements:
Kiln Dryer 12.2×10^7 Btu/hr.
Lime Kiln 2.2×10^7 Btu/hr.
The ratio of steam to direct heat required is 2.3.

F. Plant Hours of Operation at Average Conditions: 2800 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Centrifuge	1350HP	-	-	-	Motor
All other motor loads					
are in the range 300-1000 HP.					

H. Operational Considerations:

24 hour operation - 5 or 6 days per week for 4 - 5 months. Very large self generation - nationally the ratio of self generation to pruchased is 2.2.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(gaseous)	8×10^5 -	450°F	Boiler Stack
(gaseous)	10^5	450°F	Electric Gen.
(Liq.)	1.3×10^5	180°F	Non-Returned Condensate
(gaseous)	10^6	400°F	Dryer Stacks

CTAS Plant Data Sheet

Plant Name/Size: 2063- Beet Sugar, Typical plant in 100-500 employee range which accounts for 86% of energy.

		National % Distribution		Distribution for Typical Plant	
J. Fuels:	Primary Fuel	Nat. Gas	(42%) /	238	mil. Btu/hr (HHV)
	Secondary Fuel	Coal	(39%) /	221	mil. Btu/hr (HHV)
	By-product Fuel	Other	(13%) /	74	mil. Btu/hr (HHV)
		Oil	(6%)	34	mil. Btu/hr (HHV)

K. Fuels Discussion:

The natural gas is used in the kiln dryer and as boiler fuel, coal is used as coke in the Lime Kiln and also as boiler fuel and all other fuels are boiler fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
52	Sugar Beet Growing Areas	Excellent - 24 hour operation

M. Application Discussion:

The number of plants will remain stable. There has not been extensive plant building in this industry. The product demand should be stable, with any increases being at the rate of population growth.

N. Preferred Economic Criteria: 9 - 10% of Net Worth

O. Economic Discussion:

Capital expenditures in this industry were $\$35 \times 10^6$ in 1972. In general, new plant construction is low.

P. Duty Cycle and Maintenance Philosophy:

Plants operate for 24 hours - 5 or 6 days/week. Operation is seasonable - starting in the late summer and ending in the winter. In Michigan, for example, plants operate 110 - 120 days/yr.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

All electric and thermal loads are constant at levels given in C & D over 24 hour periods for 5 - 6 days per week. It is however seasonal - 4 - 5 months/yr.

CTAS Plant Data Sheet

Plant Name/Size: 2063- Beet Sugar, Typical plant in 100-500 employee range which accounts for 86% of energy.

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$100 - 150 x 10^6/yr. in 1990 time frame.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Process will be unchanged.

T. What is the national capacity for producing this product

Now in 1978	18 x 10^9 Lb/yr.
In 2000	30 x 10^9 Lb/yr.

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes are anticipated.

Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period) Per capita consumption of sugar has remained constant for some time. However competition from other sweeteners (corn syrup, etc.) is active. It is expected beet sugar will maintain its share of the sucrose market - and growth will be at a rate not faster than population (2-3%/yr). The process itself should be unchanged.

W. National energy consumed by this process

In 1978	7.5 x 10^{13} BTU/yr.
In 1985	9.3 x 10^{13} BTU/yr.
In 2000	12.5 x 10^{13} BTU/yr.

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Typical size is in the 200 x 10^6 lb/yr. range - this should not change - the mix of plant sizes should remain stable.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See Process Flow Sheets.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

In 1972, neglecting raw material costs this was 9.8%. It is estimated that this has climbed to 13% in 1978 based on energy cost that has increased more rapidly than labor costs.

CTAS Plant Data Sheet

A. Plant Name/Size: 2082-Malt Beverages (Typical of the larger plants with greater than 500 employees which currently represent 56% of the energy consumed in 2082).

B. Products:

Product	lb/yr, etc.
Beer	800×10^6
Dry Feedstuff	3.2×10^6

C. Plant Kilowatt Requirements: Average 6040 kW; Peak 7250 kW

D. Steam Requirements (Process & Heating): During bottling and packaging 2 shifts

	lb/hr	@	psig,	Returns %,	Temp. of Returns
(process)	86,000	@	15	25%	180°
(generate elec.)	6,500	@	500	100%	180°
		@			

E. Other Heat to Process (Describe):

Hot water requirements are 160° - 180° and are produced from steam. It represents 60% of the steam requirements.
Drying of wet feedstuff at 175° - 225° by burning fuel.

F. Plant Hours of Operation at Average Conditions: 6600 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Grinding Mill	640	-	-	-	elect.
CO_2 Compressor	400	-	-	-	elect.
Refrigeration	2300	-	-	-	elect.

H. Operational Considerations:

Fermentation and aging are a continuous process. Labor required is low, but the fermenting and ageing cellars are refrigerated continuously. Brew house operations vary from one to three shift operation. In older breweries, one shift operation is common. Bottling is often a one shift operation, although in larger plants two or three shifts may be used. The operation of a brewery is determined by the amount of fermenting and storage capacity. With todays' high speed filling machinery (1500 bottles or cans/minute) one shift for bottling may handle the plant capacity.

I. Waste Heat Streams:

lb/hr	Temp.	Description
172,000	400-550°	Process Boiler Stack
16,000	400-550°	Boiler Stack for elec. generation
240,000	600-700°	Dryer Stack
70,000	150°	Waste Water Including Non Returned Cond.

CTAS Plant Data Sheet

Plant Name/Size: 2082 - Malt.Beverages

		National Fuel Distribution (%)		Typical Plant Dist.
J. Fuels:	Primary Fuel	Gas (63%)	/	100 mil. Btu/hr (HHV)
	Secondary Fuel	Oil (25%)	/	40 mil. Btu/hr (HHV)
	By-product Fuel	Coal (8 %)	/	15 mil. Btu/hr (HHV)
		Other (3 %)		5 mil. Btu/hr (HHV)

K. Fuels Discussion:

Almost 25% of fuel used for drying operation. Gas used primarily for drying and boiler. The remainder used in boiler except for ~ 2 - 3% used for in-plant transportation.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Growth rate for malt beverages has been estimated at about 4% per year. More recent estimates are a growth rate of about double this. However, the higher figure is based on the fact that there has been a high increase in the last two years. It may be too early to determine whether the high rate will continue but it has held for the last few

M. Application Discussion:

years. In general, the large companies are taking over the market. These companies have been building large breweries and in some cases super large industries. With approximately 24 plants of the typical size or larger in operation now, it is anticipated that in the years 1990-2000 another 10-20 plants in this size range will be constructed or expanded to this size. The cogeneration potential is good because of 24 operation and electric-steam demand.

N. Preferred Economic Criteria: Return on net worth ~ 13.9%.

O. Economic Discussion:

The capital expenditures range from $150-200 million per year.

P. Duty Cycle and Maintenance Philosophy:

The fermentation, ageing and refrigeration are a 24 hour a day operation. Brew house is a 2-3 shift operation for a large plant and bottling may be 2-3 shift operation. This typical plant is assumed to operate 3 shifts per day for 5 to 6 days/wk.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

24 hour electric load of about 6.040 Kw and a process steam load of 86,000 lb/hr.

<u>CTAS Plant Data Sheet</u>

Plant Name/Size: 2082 - Malt Beverages

R. Describe the level of capital investment in this industry. (1985-2000 time period)

In the year 2000 this is estimated at \$300 - \$400 million/yr.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

The process attached is typical of the present day operations and the 1990 time frame.

T. What is the national capacity for producing this product

Now in 1978 $50 - 60{,}000 \times 10^6$ lb/yr

In 2000 $90 - 110{,}000 \times 10^6$ lb/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

One possible change would be to do the mashing operation at a central plant. The filtered product called "wort" would be concentrated by evaporation. The concentrated wort would then be shipped to regional plants where it is reconstituted, (contd next page).

Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Growth trends estimated at ~ 4%/year for the long range; however, recent estimates are about double this based on recent experience.

W. National energy consumed by this process (fossil plus elec. x 3 = total BTU/yr).

In 1978 750 x 10" BTU/yr

In 1985 1200 x 10" BTU/yr

In 2000 1900 x 10" BTU/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Typical size today and future are at 800×10^6 lb/yr and larger. Some plants up to $2{,}000 \times 10^6$ lb/yr.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached process flow diagram.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

~ 4%

This is a percentage of value added which does not include cost of raw material or profits but includes all other cost.

U. (Continued)

fermented, aged and bottled. This is currently being done by one European brewer, where concentrated wort is shipped to Florida. An American firm is doing this to supply markets in Hawaii and Alaska. This allows more efficient use of the brew house at the central plants and eliminates the need for a brew house and raw ingredients handling facilities at satellite plants.

3.0 TEXTILE INDUSTRY (SIC 22)

3.1 General - The textile industry is composed of the following categories:

SIC 22 - Textile Mill Products - Weaving Mills

SIC 225 - Knitting Mills - Hoisery, Underwear

SIC 2?5 - Finishing Plants - Except Wool

SIC 227 - Floor Covering Mills - Carpets, Rugs

SIC 228 - Yarn and Thread Mills

SIC 229 - Miscellaneous Textile Goods - Upholstery, Lace, Tire Cord, Non-wovens

In reviewing each of these categories in terms of energy usage and steam requirements, we have selected SIC 226 - Fininshing Plants - as the most viable for a cogeneration study.

3.2 Textile Finishing (SIC 226) - The finishing industry had 655 plants in 1972, employing 79,500 people. The industry shipped $2.5 billion of goods or an average of $3.8 million per plant. Finishing mills employing 100 or more persons produced 86 percent of industry output. Plants with more than 500 employees produced 35 percent of the industry total.

Capital investment in 1976 as compiled by the American Textile Manufacturers Institute (ATMI) follows:

SIC NO.	CAPITAL INVESTMENT - MILLION DOLLARS BUILDINGS	EQUIPMENT	TOTAL
22610 - Cotton Broadcloth	$ 2.5	$ 21.3	$ 23.8
22620 - Manmade Fibers	15.1	66.9	82
22690 - Other	2.4	8.6	11
			$116.8

3.2.1 General Process Description

Input Materials - The primary inputs to textile finishing are broad woven fabrics, dyes, lakes and toners. Broad woven fabrics made up 52 percent of the inputs by value to textile finishing in the 1972 census data. Dyes, lakes, and toner made up an additional 19 percent by value.

Product Output is finished cloth that is shipped to apparel manufacturers and other miscellaneous fabric manufacturers.

3.2.1 General Process Description - Continued

List of Unit Operations

- Singing
- Desizing
- Scouring
- Bleaching and Washing
- Mercerizing
- Dying or Printing
- Drying
- Shipping

Major Energy Uses - The largest motors utilized are in the printing department where 50 horsepower motors are common. Natural gas is used in the singers and drying ovens.

Criticality of Power Failures - In event of a power failure, no hazard will occur to employees, such as exposions, dangerous gases, etc. Cloth could be damaged if left in bleaching vats.

Process Modification for Cogeneration - Natural gas and steam are presently used in the process. The natural gas is used for singing and drying cloth. Cogeneration would possibly be more attractive if electric drying ovens could be used for drying cloth in lieu of natural gas. However, the present process equipment available requires high heat for drying, which can only be achieved by using natural gas. At present we do not know of a modification that will enhance cogeneration.

Average Energy Consumption - Approximately 0.3 KW of electricity per yard of processed cloth is consumed.

3.2.2 Industry Capacity - The approximate national industry capacity is 12 billion yards of cloth per year. From 1964 to 1975, the industry has averaged 10 billion yards of cloth per year. The highest production rate occurred in 1966 in which 11 billion yards of cloth were produced. The lowest production rate occurred in 1975 when 8.4 billion yards of cloth were produced.

Process Changes - No process changes are anticipated in the near future. However, gas or oil fired power boilers will be converted to coal.

Growth Trends - Zero growth is anticipated due to present excess capacity, foreign imports, and low profit margins. Any new plants that may be built would result in the closing of smaller less efficient plants.

3.2.2 Industry Capacity - Continued

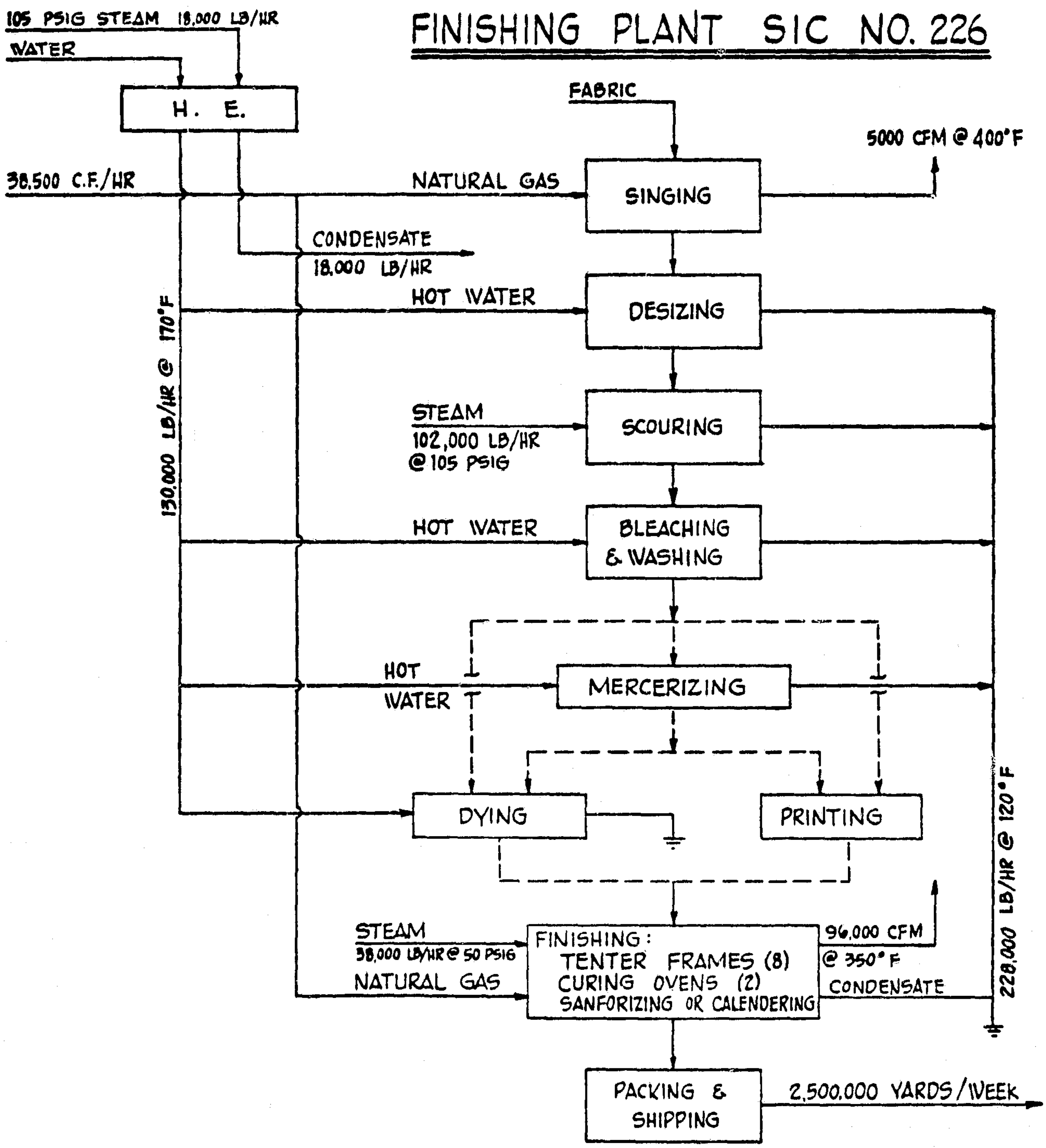
Total Energy Consumed

1978 - 21 Billion KWH Per Year
1985 - Same
2000 - Same

The above is based on zero growth of the industry.

Typical Plant Capacity - In 1972, 655 plants produced 10 billion yards of cloth and employed 79,500 people. This averages 15.3 million yards per year of cloth per mill and 121 employees per mill. The larger mill will average 130 million yards of cloth per year with 800 employees per mill.

Typical Plant Size During the Period 1985 - 2000 - If new plants are built, they will replace many smaller and inefficient plants with no increase in total industry output. Another possibility is that the smaller plants will gradually be closed and the larger plants will increase production to cover the production loss of the smaller mills. We estimate that the typical plant in 1985 - 2000 will produce 2.5 million yards of cloth per week, with 800 employees.



FINISHING PLANT SIC NO. 226
105 PSIG STEAM 18,000 LB/HR
WATER
H. E.
FABRIC
5000 CFM @ 400°F
38,500 C.F./HR
NATURAL GAS
SINGING
CONDENSATE
18,000 LB/HR
HOT WATER
DESIZING
130,000 LB/HR @ 170°F
STEAM
102,000 LB/HR
@ 105 PSIG
SCOURING
HOT WATER
BLEACHING
& WASHING
HOT
WATER
MERCERIZING
DYING
PRINTING
228,000 LB/HR @ 120°F
STEAM
38,000 LB/HR @ 50 PSIG
NATURAL GAS
FINISHING:
TENTER FRAMES (8)
CURING OVENS (2)
SANFORIZING OR CALENDERING
96,000 CFM
@ 350°F
CONDENSATE
PACKING &
SHIPPING
2,500,000 YARDS/WEEK

CTAS Plant Data Sheet

A. Plant Name/Size: Textile Finishing - SIC 226

B. Products:

Product	lb/yr, etc.
Finished Broadwoven fabrics	2,500,000 yards/week

C. Plant Kilowatt Requirements: Average 6200 kW; Peak 6600 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
38,000	@	50	30%	180°F
102,000	@	105	30%	212°F
18,000	@	105	100%	212°F

E. Other Heat to Process (Describe):

Natural gas used for singing and drying ovens = 38.5 mil. BTU/HR

F. Plant Hours of Operation at Average Conditions: 6240 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
50	50	1800	N/A	Electric

H. Operational Considerations:

24 hr/day - 5 day week = 6240 hr/yr.

I. Waste Heat Streams:

lb/hr	Temp.	Description
228,000 lb/hr	120° F	Contaminated Waste Water
5,000 CFM	400° F	Singing Discharge - Air
96,000 CFM	350° F	Finishing Discharge - Air

CTAS Plant Data Sheet

Plant Name/Size: Textile Finishing - SIC 226 - 2,500,000 yards/week.

J. Fuels: Primary Fuel Coal / 158 mil. Btu/hr (HHV)

Secondary Fuel Natural Gas or Oil For Process / 38.5 mil. Btu/hr (HHV)

By-product Fuel None / mil. Btu/hr (HHV)

K. Fuels Discussion:
Natural gas and/or oil will continue to be used for direct firing applications on process equipment. Coal will be used in the future for producing steam.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
No New Plants		Marginal in existing Plants

M. Application Discussion:

Marginal for cogeneration due to:

a) Low electrical requirements (6200kw)
b) 5 day/week operation

* N. Preferred Economic Criteria: Data of a priority nature and not available.

O. Economic Discussion: See "N"

P. Duty Cycle and Maintenance Philosophy:

24 hour/day - 5 day week = 6240 hr/yr.

Maintenance done on weekends and occasional shutdowns.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Textile Finishing - SIC 226-2,500,000 yards/week

R. Describe the level of capital investment in this industry. (1985-2000 time period)

1976 - $\$117 \times 10^6$
1985 - $\$149 \times 10^6$
2000 - $\$201 \times 10^6$

Note: Capital investment is based on zero growth for the years 1976-2000. Escalation estimated @ 3% per year.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Not a new process.

T. What is the national capacity for producing this product

Now in 1978 $10,000 \times 10^6$ yards

In 2000 $10,000 \times 10^6$ yards

No growth

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Present gas or oil fired power boilers will be converted to coal.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

No growth is anticipated due to present excess capacity, foreign imports, and low profit margins.

W. National energy consumed by this process

In 1978 22 Billion KWH per year

In 1985 Same

In 2000 Same

X. Describe the typical size of this plant today and how that will change in 1985-2000.

In 1972, finishing plants employing 100 or more persons produced $2.25 billion of output or 86 per cent of industry output. Plants with more than 500 employees had $917 million of shipments or 35 percent of industry output.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See block diagram.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Data is not available for total operating costs. Various mills that we interviewed estimated a range of 15 to 20 per cent of total operating costs as the cost of energy.

4.0 LUMBER AND WOOD PRODUCTS SIC 24

4.1 This industry is concerned with the production of lumber, plywood, particle board, and other wood products. Wood product mills in general vary in size from small "dirt mills" to large integrated forest products complexes producing on site all of the above mentioned products. In 1972 there were 8,071 establishments in the U.S.A., of which 1717 had more than 20 employees, 343 had 100 or more employees, and 266 had 100 to 249 employees.

The typical operating schedule of a large sawmill is two shifts per day, five days per week for wood preparation, sawing, and planing operations, and 7 days per week operations for drying.

This industry averages 3.9% of product value added as energy. A large portion of the process steam is generated from wood waste and most electricity is purchased.

4.2 Softwood Lumber; SIC 2421

There will be approximately 40 billion board feet of lumber produced in 1978. No basic changes are foreseen in the industry in the years 1985 - 2000. Production should rise to 80 billion BF by the year 2000 with a one billion dollar capital investment over the period 1985 - 2000.

4.2.1 The raw material for the process is timber. The product output is finished building lumber. The process includes, debarking, sawing to length, removing undesirable wood, sawing timber lengthwise into rectangular cross section, separating the green lumber, grading, stacking, drying and planing.

The major energy use is drying. Power failures are not critical to the process. The potential for cogeneration is good in a large wood products complex. The average energy consumption per board foot production is 6000 BTU nationally.

4.2.2 The national capacity for production of this process is 40 billion board feet. 37 billion board feet were produced in 1977 by 1,982 United States plants. There is presently a rapid movement to burn wood for industrial energy. Direct fired drying, as opposed to steam drying is popular. The trend toward small timber will reduce the precent of lumber used. Composition panels and boards bound together will substitute for lumber, however, small lumber sizes will increase in use as opposed to larger boards and timbers. The national energy use in 1978 is 237 X 10^{12} BTU. In 1985 it will be 300 X 10^{12} BTU, and in 2000, 400 X 10^{12} BTU.

The following is a tabulation of plant sizes in the United States:

PRODUCTION RANGE - BF	NO. OF PLANTS
50 - 300 MM	221
25 - 50 MM	273
10 - 25 MM	402
5 - 10 MM	329
3 - 5 MM	261
Other	496
	1,982 Total for 1977

The expected plant capacity in 1985 - 2000 will be 50 MM BF.

4.2.3 Plant kilowatt requirements are 1500 KW average. Steam requirements are 30,000 lb/hr @ 125 psig. Plant hours of operation are 4000 hr/yr. Large horsepower loads include:

Chipping Head	100 Hp - 1800 RPM
Chipper	100 Hp - 1200 RPM
Blower	100 Hp - 1800 RPM

Waste heat stream is kiln exhaust, air @ 180° F. - 6MM BTU/hr.

Load profiles are uniform with no load when plant is down.

4.3 Softwood Plywood SIC 2436 Softwood Veneer SIC 2435

There will be approximately 19 billion square feet of 3/8" softwood plywood produced in 1978. There is a foreseeable trend toward direct firing of veneer dryer to reduce final cost. Production will rise to 74 billion square feet in 2000 with a $6 billion capital investment over the period 1985 - 2000.

4.3.1 The raw material for the process is timber. The product output is plywood. The process includes, debarking, cutting the timber into veneer, drying the veneer, applying glue to the veneer surface, binding the sheets of veneer together in a heated press, and finishing edges and surfaces. The major energy use is drying. Power failures are not critical. The average energy consumed per square foot is 5000 BTU.

4.3.2 The national capacity for production of softwood plywood is 20 billion square feet, with 19 billion to be produced in 1978. The anticipated production in 2000 is 74 billion square feet. There is a trend toward direct firing of veneer dryers to reduce final cost. The national energy consumption in 1978 is 100 X 10^{12} BTU. The national energy consumption in 2000 will be 275 X 10^{12} BTU. Nationally, the average plant capacity is 55 MM square feet. Today's average new plant size is 100 million S.F., in 1985 - 2000 this size will increase to 200 MM to 300 MM S.F.

4.3.3 The electric load to produce 100 MM S.F. of plywood is 3000 KW. The steam required is 75,000 lb/hr @ 250 psig with 90% returns at 250° F. Plant hours of operation are 6000 hr/yr. Large horsepower loads are lathe @ 150 Hp - 1800 RPM, fan at 100 Hp - 1800 RPM. Waste heat stream is dryer exhaust (air) at 13 MM BTU/hr 200° F. Heat is recoverable down to 160° F. Energy load profiles are uniform with no load when the plant is down. The primary fuels that are byproducts, are bark and sawdust.

4.4 Particle Board

There will be approximately 4 billion square feet (3/4" basis) of particle board produced in 1978. No basic changes are foreseen in the industry in the 1985 - 2000 time period. Production should rise to 23.8 billion in 2000, with a $3.9 billion capital investment between 1985 and 2000.

4.4.1 The raw material is wood chips. The production output is particle board. The process includes receiving wood chips, planer shavings, and sawdust, size reduction by flaking and/or refining (steaming may also be used in this step), dry by direct steaming, add urea formaldehyde binder, spread uniformly in a flat sheet, press to thickness. The major energy use is drying. Power failure can be slightly critical, but fire controls can be added to offset this danger. The average energy consumed per square foot is 9,700 BTU/S.F.

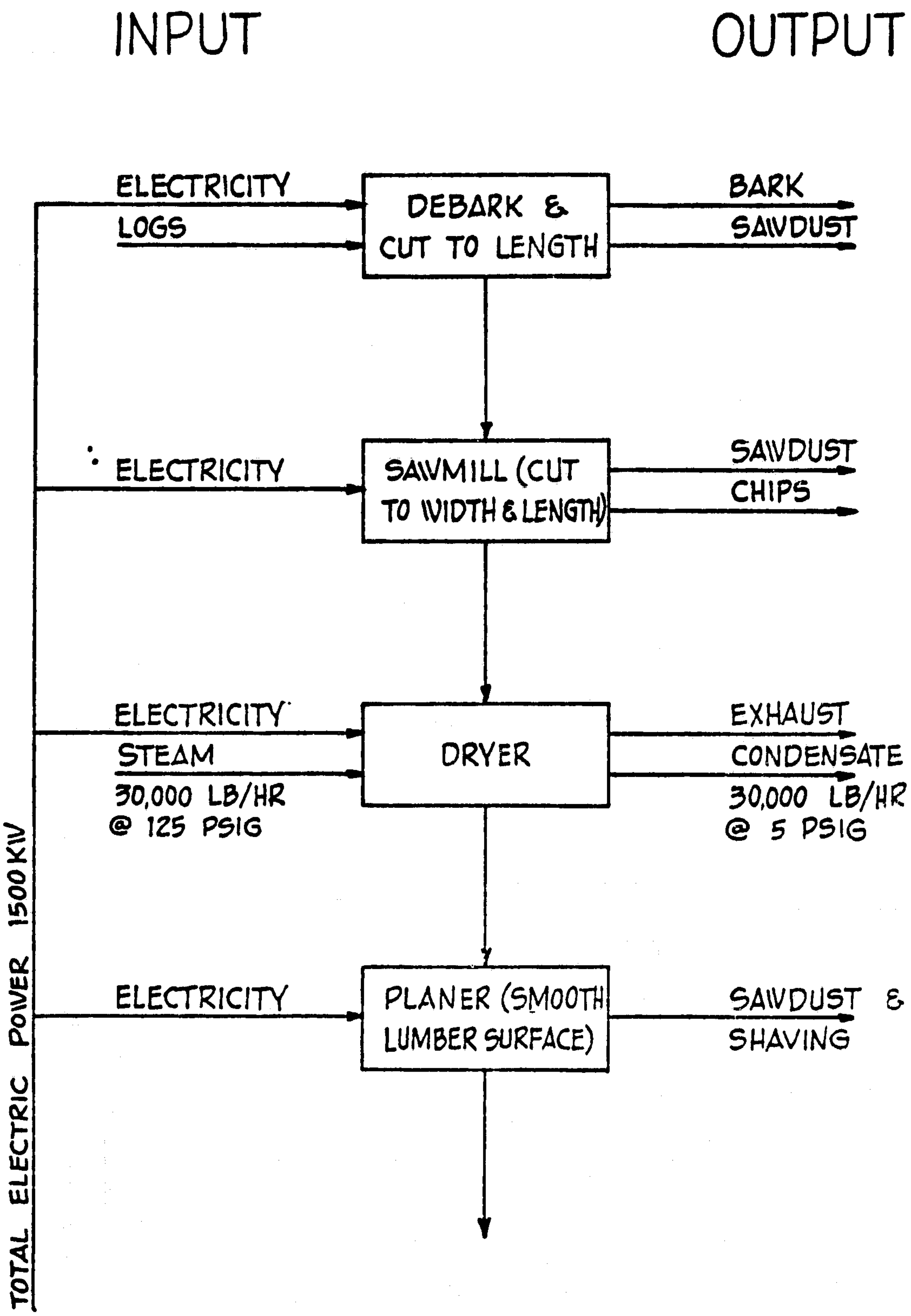
4.4.2 The national capacity for production of this product is 4 billion square feet. Production in 1978 will be 3.4 billion. Shifts are being made to reduce the consumption of oil and gas by substituting coal and wood. The use of particle board is increasing rapidly as smaller timber is harvested for lumber production. Total national energy usage is 32 X 10^{12} BTU/yr. The average plant size is 48 MM S.F. The typical modern facility is 100 MM S.F. The typical facility in 1985 - 2000 is expected to be 100 to 200 MM S.F.

4.4.3 The electric load to produce 80 MM S.F. of 3/4" thick board is 5000 KW. The steam required is 37,000 lb/hr @ 250 psig. The fiber drying process is direct fired with natural gas wood or oil at 55 MM BTU/hr. Plant hours of operation are 8000 hrs/yr. Large horsepower loads are refiner 700 Hp @ 1800 RPM, press 200 Hp @ 1800 RPM, and transport planer 200 Hp @ 1800 RPM. Waste heat streams are refiner exhaust 20,000 lb/hr @ 225° steam, and press and drying exhaust 15 MM BTU/hr @ 225° F. Both are recoverable down to 160° F. Fuels are natural gas 50 MM BTU/hr, and oil 37 MM BTU/hr.

Thermal and electric loads are straight line except during maintenance shutdowns.

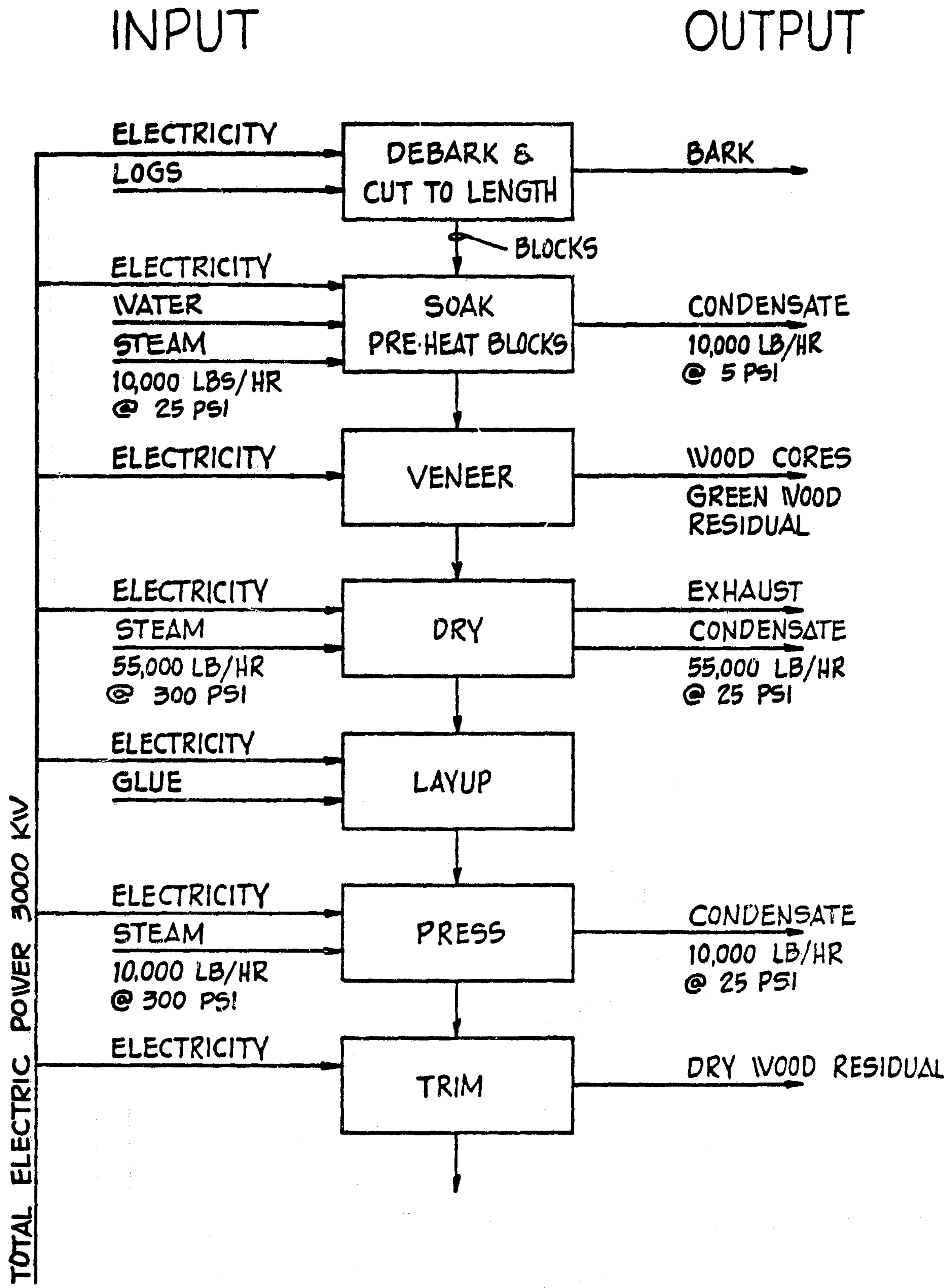
SOFTWOOD LUMBER

50 MM BF/YEAR



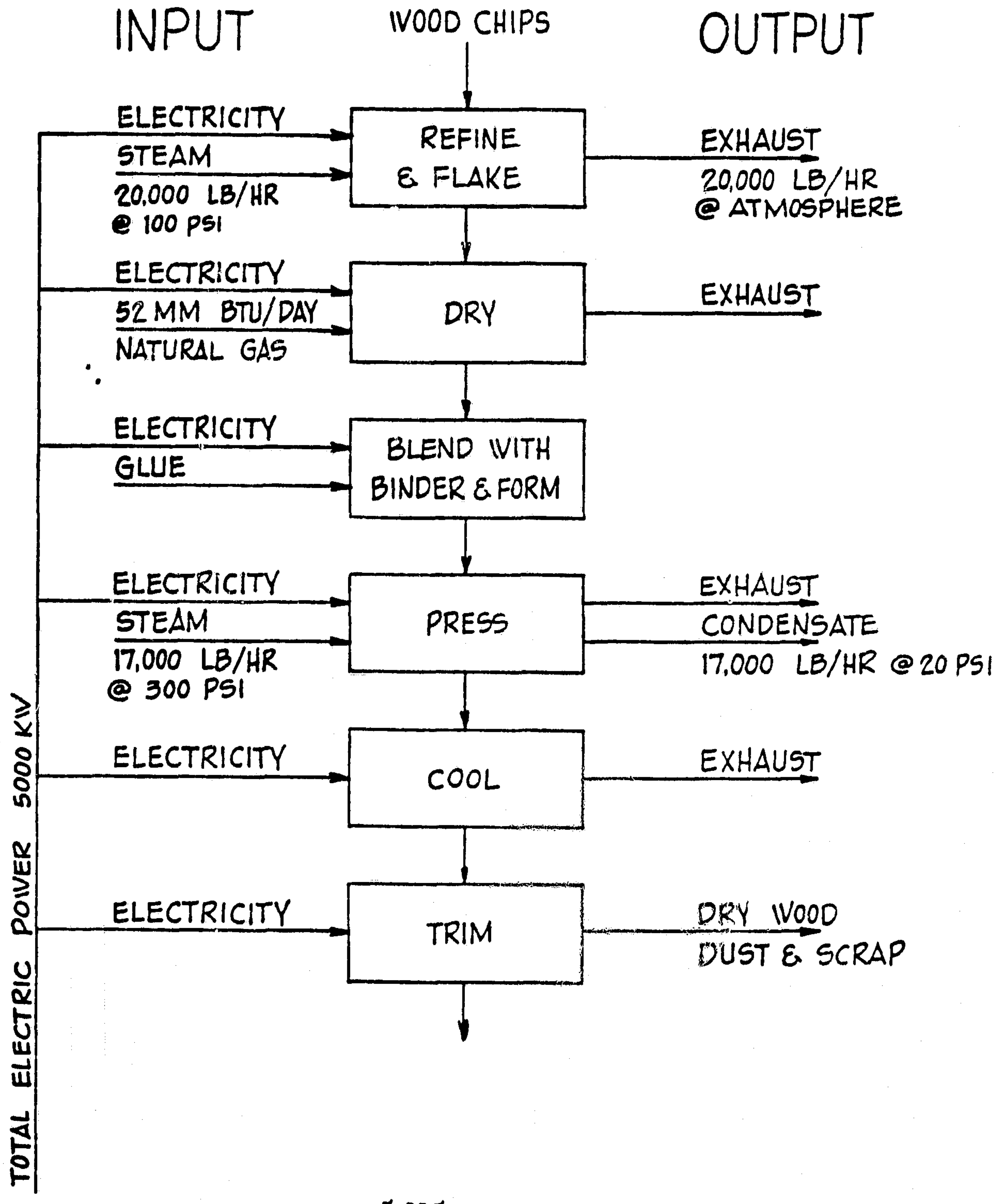
SOFTWOOD PLYWOOD

100 MMSF (3/8" BASIS)



PARTICLE BOARD 80MMSF

(3/4" BASIS)



CTAS Plant Data Sheet

A. Plant Name/Size: Softwood Lumber; SIC 2421

B. Products:

Product	lb/yr, etc.
Dimension Lumber	50 million Board FT./year

C. Plant Kilowatt Requirements: Average 1500 kW; Peak 1700 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
30,000	@	125	90	$200^{o}F$

E. Other Heat to Process (Describe):

None

F. Plant Hours of Operation at Average Conditions: 4000 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
100	200	1800	Constant	Motor
100	150	1200	Constant	Motor
100	100	1800	Constant	Motor

H. Operational Considerations:

16 Hour/Day - 5 Days/week - 50 Weeks/year = 4000 hr/year

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(AIR)	6 MM BTU/HR	$180^{o}F$	Kiln exhaust

CTAS Plant Data Sheet

Plant Name/Size: Softwood Lumber: SIC 2421: 50 MM BF

J. Fuels: Primary Fuel Bark and Sawdust / 50 mil. Btu/hr (HHV)

Secondary Fuel Oil / mil. Btu/hr (HHV)

By-product Fuel Bark/Sawdust / mil. Btu/hr (HHV)

K. Fuels Discussion:

Bark or sawdust from the timber processed is the primary fuel supplemented with oil depending on the particular process arrangement.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
200	Across U.S. with primary growth in the south.	Good

M. Application Discussion:

Cogeneration potential increases as sawmills become part of a large wood products comples.

N. Preferred Economic Criteria: No Data Available

O. Economic Discussion:

See "N"

P. Duty Cycle and Maintenance Philosophy:

Plants operate 4000 hours/year with one to two days per week for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Softwood Lumber

R. **Describe the level of capital investment in this industry.** (1985-2000 time period)

The capital investment perhaps will be 100 plants at $10 million or $1 Billion (todays dollars).

S. **If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.**

Process is commercial

T. **What is the national capacity for producing this product**

Now in 1978 40 billion BF

In 2000 80 billion BF

U. **Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.**

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

See narrative description.

W. National energy consumed by this process

In 1978 237×10^{12} Btu

In 1985 300×10^{12} Btu

In 2000 400×10^{12} Btu

X. Describe the typical size of this plant today and how that will change in 1985-2000.
The average plant size is 20×10^6 BF/year. Plants added to capacity will be 50×10^6 BF/yr to 200×10^6 BF/yr. Small plants will be closed.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See G, D and J.

CTAS Plant Data Sheet

A. Plant Name/Size: SIC 2436 Softwood Plywood

B. Products:

Product	lb/yr, etc.
Plywood	100 Million Sq. Ft./Yr. 3/8" Thick

C. Plant Kilowatt Requirements: Average 3000 kW; Peak 3500 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
75,000	@	250	90	$250^{o}F$

E. Other Heat to Process (Describe):

None

F. Plant Hours of Operation at Average Conditions: 6000 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Lathe	150	200	1800	Constant	Motor
Fan	100	100	1800	Constant	Motor

H. Operational Considerations:

24 Hr/Day - 5 Day/Week - 50 Weeks/Year = 6000 Hr/Yr

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(Air)	13MM BTU/Hr	$200^{o}F$	Dryer Exhaust

CTAS Plant Data Sheet

Plant Name/Size: Softwood Plywood 100 MM SF (3/8" Basis)

J. Fuels: Primary Fuel Bark / 130 mil. Btu/hr (HHV)
Secondary Fuel Oil / mil. Btu/hr (HHV)
By-product Fuel Bark / mil. Btu/hr (HHV)

K. Fuels Discussion:

Bark from the timber processed is the primary fuel, supplemented with oil depending on the particular process arrangement.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
400	Across U.S. with primary	Good

M. Application Discussion:

Cogeneration potential increases as plywood is produced in large wood products complexes.

N. Preferred Economic Criteria: Data Not Available

O. Economic Discussion:

See "N"

P. Duty Cycle and Maintenance Philosophy:

Plants operate 6000 hours/year with one to two days per week for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Softwood Plywood

R. Describe the level of capital investment in this industry. (1985-2000 time period)

The capital investment will be 200 plants at $30 million each or $6 Billion Total (todays dollars).

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Process is commercial

T. What is the national capacity for producing this product

Now in 1978 20 billion SF

In 2000 74 billion SF

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

See narrative report.

W. National energy consumed by this process

In 1978 100×10^{12} BTU

In 1985 150×10^{12} BTU

In 2000 275×10^{12} BTU

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The average plant size built today is 100 MM SF (3/8" Thick). The average plant size added in the 1985-2000 period will be 200 MM SF to 300 MM SF.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See G, D and J.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

CTAS Plant Data Sheet

A. Plant Name/Size: SIC 2492 - Particle board

B. Products:

Product	lb/yr, etc.
Particle board	80 million Sq. Ft./Yr. - 3/4" Thick

C. Plant Kilowatt Requirements: Average 5000 kW; Peak 6000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
37,000	@	250	40%	300°F

E. Other Heat to Process (Describe):

Direct fired fiber drying with natural gas, wood, or oil at 50 MM Btu/hr.

F. Plant Hours of Operation at Average Conditions: 8000 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Refiner	700	700	1800	Constant	Motor
Press	200	200	1800	Constant	Motor
Transport	200	200	1800	Constant	Motor

H. Operational Considerations:

Continuous 24 hrs/Day - Approximately 6 Days/week

One day or less per week required for maintenance

I. Waste Heat Streams:

lb/hr	Temp.	Description
20,000 - Steam	225°F	Exhaust from Refining Operation
15 MM BTUH-Air	225°F	Press and Drying Exhaust

CTAS Plant Data Sheet

Plant Name/Size: SIC 2492 Particle board 80 MM SF/yr.

J. Fuels: Primary Fuel Natural gas / 50 mil. Btu/hr (HHV)
Secondary Fuel Oil / 37 mil. Btu/hr (HHV)
By-product Fuel Wood / -- mil. Btu/hr (HHV)

K. Fuels Discussion:

Wood is fast becoming the primary fuel to produce steam and direct heat for drying in this process.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
25	Across U.S. with primary growth in the south.	Good

M. Application Discussion:

Cogeneration potential increases as particle board plants become part of a large wood products complex.

N. Preferred Economic Criteria: No Data Available

O. Economic Discussion:

See "N"

P. Duty Cycle and Maintenance Philosophy:

Plants operate 8000 hours/year with one day or less/week for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

Uniform loading with essentially no load when plant is down. The only cycle is the press steam which varies 5,000 lbs/hr every five minutes more or less.

CTAS Plant Data Sheet

Plant Name/Size: Particle board

R. Describe the level of capital investment in this industry. (1985-2000 time period)

The capital investment will be 130 plants at $30 million each = $3.9 billion.

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
This process is commercial.

T. What is the national capacity for producing this product

Now in 1978 3.4 billion SF (3/4" thick)

In 2000 23.8 billion SF (3/4" thick)

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Refer to narrative report.

W. National energy consumed by this process

In 1978 32×10^{12} BTU

In 1985 100×10^{12} BTU

In 2000 172×10^{12} BTU

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The average particle board plant is 50 MMSF/year. Perhaps the average plant in 1985 - 2000 will produce 100 - 200 MMSF/year.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See G, D & J.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

5.0 PULP AND PAPERBOARD MILLS NO. 2611, 2621, 2631

5.1 This industry is concerned with the production of pulp and paper products from organic fibrous materials, primarily wood, by mechanical, thermo-mechanical or chemical processes. As a whole, the industry is highly energy intensive and is committed to on-site steam and electric generation. Mills generally operate 24 hours a day, 350 days per year, and employ 325 people per 1000 ton per day production rates. As a whole, the industry growth rate is 3% per year and is expected to continue to grow at this rate for the period 1985 - 2000. The major energy uses in industry are pulping, refining, bleaching, liquor recovery, and drying. All processes depend heavily on a constant and dependable power supply and maintain ties with their local utilities for backup in case of failure of on-site facilities.

5.2 Waste Paper Mills will produce approximately 86,300 tons per day of product in the year 2000. No major changes are anticipated in the basic process in the time period between 1985 and 2000, but it is foreseen that there will be a major turnover in fuel use from oil to coal for steam and electric power generation. Production of products from wastepaper is expected to increase at 3% per year with a level of capital investment of $26.3 X 10^9 in the 1985 - 2000 time period.

5.2.1 Input materials are wastepaper, water, and coal. Product output is a variety of paper products, i.e., tissue and boxboard. Unit operations are receiving and storage, pulping (includes screening and bleaching), refining, blending, forming, and drying. Power ties are maintained with the utility for backup in case of power failure. Some wastepaper operations are cogenerators. The average energy consumption per unit of primary process output is 3.9 X 10^6 WH/ton and 12% of total operating costs are costs of energy.

5.2.2 The national capacity for the process is 14 X 10^6 tons per year. The only major change anticipated in the industry is adaptation to coal as the primary fuel source. The growth trend anticpated is 3% per year. The anticipated total energy consumed in 1978 by the process is 127 X 10^6 MWH per year. The range of sizes is 20 - 600 TPD. A typical modern facility will produce 600 TPD. The expected plant size in the period 1985 - 2000 will produce 600 tons per day of product.

5.2.3 Plant kilowatt requirements average 15,000 KW. Steam requirements are 52,000 lb/hr @ 70 psig and 192,000 lb/hr @ 150 psig. Plant hours of operation are 8400 hr/yr. Large horsepower loads include, fan pump drive @ 600 Hp and paper machine drives 2 @ 1300 Hp and 5 @ 700 Hp. Waste heat streams are paper machine overflow to sewer @ 110° F. - 9 X 10^5 lb/hr - and paper machine hood exhaust @ 240° F. - 1.4 X 10^6 lb/hr. It would not be practical to recover heat from the paper machine overflow. Heat can be recovered from the hood exhaust down to 160° F. The primary fuel is coal.

Thermal and electrical load profiles are straight line because of continuous operation.

5.3 Unbleached Kraft Mills will produce approximately 110,000 tons of product per day in the year 2000. No major changes are anticipated in the basic process in the time period between 1985 and 2000, but it is foreseen that there will be a major turnover in fuel use from oil to coal for steam and electric power generation. Production of products from unbleached Kraft pulp is expected to increase at 3% per year with a level of capital investment of \$33.6 X 10^9 in 1985 - 2000.

5.3.1 Input materials are wood, water, chemicals, and coal. Product output is a variety of paper products, i.e. liner board and bags. Unit operations are chipping, cooking, washing, liquor recovery, refining, blending, forming, and drying. Major energy users are pulping, refining, drying and liquor recovery. Power ties are maintained with the utility for backup in case of power failure. Most Kraft pulping operations are cogenerators. The average energy consumption per unit of primary process output is 7.4 X 10^6 WH/ton and 7% of total operating costs are costs of energy.

5.3.2 The national capacity for the process is 18 X 10^6 tons/yr. The only major change anticipated in the industry is adaptation to coal as the primary fuel source. The growth trend anticipated is 3% per year. The anticipated total energy consumed in 1978 by the process is 310 X 10^6 MWH/yr. The range of plant sizes is 250 - 3000 TPD. A typical modern facility will produce 1000 TPD. The expected plant size in the period 1985 - 2000 is 1000 TPD.

5.3.3 Plant kilowatt requirements average 29,000 KW. Steam requirements are 4.2 X 10^5 lb/hr @ 70 psig and 1.4 X 10^5 lb/hr @ 150 psig. Plant hours of operation are 8400 hr/yr. Large horsepower loads include paper machine drive 2 @ 2200 Hp and 5 @ 1200 Hp, kiln draft fan drive 600 Hp, and fan pump drive 1000 Hp. Waste heat streams are paper machine hood exhaust 15 X 10^5 lb/hr @ 240° F., paper and pulp mill sewers 94 X 10^5 lb/hr @ 110° F., and lime kiln exhaust 32,000 lb/hr @ 180° F. It would not be practical to recover heat from the sewer overflow. Heat can be recovered from the hood exhaust down to 160° F., and from the kiln down to 120° F. The primary fuel is coal.

Thermal and electrical load profiles are straight line because of continuous operation.

5.4 Bleached Kraft Mills will produce approximately 79,000 tons of product per day in the year 2000. No major changes are anticipated in the basic process in the time period between 1985 and 2000, but it is foreseen that there will be a major turnover in fuel use from oil to coal for steam and electric power generation. Production of products from bleached Kraft pulp is expected to increase at 3% per year with a level of capital investment of \$48.9 X 10^9 in 1985 - 2000.

5.0 PULP AND PAPERBOARD MILLS NO. 2611, 2621, 2631 - Continued

5.4.1 Input materials are wood, water, chemicals, and coal. Product output is a variety of paper products, i.e. tissue, fine paper, and bleached liner board. Unit operations are chipping, cooking, washing, liquor recovery, bleaching, refining, blending, forming and drying. Major energy users are pulping, refining driving, bleaching, and liquor recovery.

5.4.2 The national capacity for the process is 14 X 10^6 tons/yr. The only major change anticipated in the industry is adaptation to coal as the primary fuel source. The growth trend anticipated is 3% per year. The anticipated total energy consumed by the process is 343 X 10^6 MWH/yr. The range of plant sizes is 250 - 3000 TPD. A typical modern facility will be 1000 TPD. The expected plant size in the period 1985 - 2000 is 1000 TPD.

5.4.3 Plant kilowatt requirements average 50,000 KW. Steam requirements are 4.1 X 10^5 lb/hr @ 70 psig and 3.8 X 10^5 lb/hr @ 150 psig. Plant hours of operation are 8400 hr/yr. Large horsepower loads include paper machine drive with 2-2500 Hp and 5-1400 Hp motors, kiln draft fan drive 800 Hp, and fan pump drive 3000 Hp. Waste heat streams are paper machine hood exhaust 15 X 10^5 lb/hr @ 240 F., paper and pulp mill sewers 13.4 X 10^6 lb/hr @ 110 ° F., lime kiln exhaust 32,000 lb/hr @ 180° F., and chlorination sewer @ 5.5 X 10^6 lb/hr. It would not be practical to recover heat from the paper, pulp or chlorination sewer. Heat can be recovered from the paper machine hood exhaust down to 160° F. and from the kiln down to 120° F. The primary fuel is coal.

Thermal and electrical load profiles are straight line because of continuous operation.

5.5 Neutral Sulfite Semi-Chemical will produce approximately 23,000 tons of product per day in the year 2000. No major changes are anticipated in the basic process in the time period between 1985 and 2000, but it is foreseen that there will be a major turnover in fuel use from oil to coal for steam and electric power generation. Production of products from unbleached NSSC-pulp is expected to increase at 3% per year with a level of capital investment of \$7.8 X 10^6 in 1985 - 2000.

5.5.1 Input materials are wood, water, chemicals, and coal. Product output is corrugation medium. Unit operations are chipping, digesting, refining, washing, stock preparation, forming, drying, and finishing. Major energy uses are digesting, refining, drying, and liquor recovery. Power ties are maintained with the utility for backup in case of power failure. Most NSSC operations are cogenerators with Kraft Mills. The average energy consumption per unit of primary process output is 4.7 X 10^6 and 17% of total operating costs are costs of energy.

5.5.2 The national capacity for the process is 4.4 X 10^6 tons/hr. The only major change anticipated in the industry is adaptation to coal as the primary fuel source. The growth trend anticipated is 3% per year. The anticipated total energy consumed by the process is 4.1 X 10^6 MWH/yr. The range of sizes is 200 - 600 TPD. A typical modern facility will produce 400 TPD. The expected plant size in the period 1985 - 2000 is 600 TPD.

5.5.3 Plant kilowatt requirements average 20,000 KW. Steam requirements are 95,000 lb/hr @ 70 psig and 212,000 lb/hr @ 150 psig. Plant hours of operation are 8400 hr/yr. Large horsepower loads include, paper machine drive with 2-2000 Hp and 5-1000 Hp motors, and fan pump drive 600 Hp. Waste heat streams are pulp and paper mill sewers 4.8 X 10^6 lb/hr @ 110° F., and paper machine hood exhaust 9 X 10^5 lb/hr @ 240° F. It would not be practical to recover heat from the paper, or pulp mill sewers. Heat can be recovered from the paper machine hood exhaust down to 160° F. The primary fuel is coal.

Thermal and electrical load profiles are straight line because of continuous operation.

5.6 Thermo-Mechanical Pulping will produce approximately 28,493 tons of product per day in the year 2000. No major changes are anticipated in the basic process in the time period between 1985 and 2000, but it is foreseen that there will be a major turnover in fuel use from oil to coal for steam and electric power generation. Production of products form thermo-mechanical pulp is expected to increase at 3% per year with a level of capital investment of \$10.7 X 10^6 in 1985 - 2000.

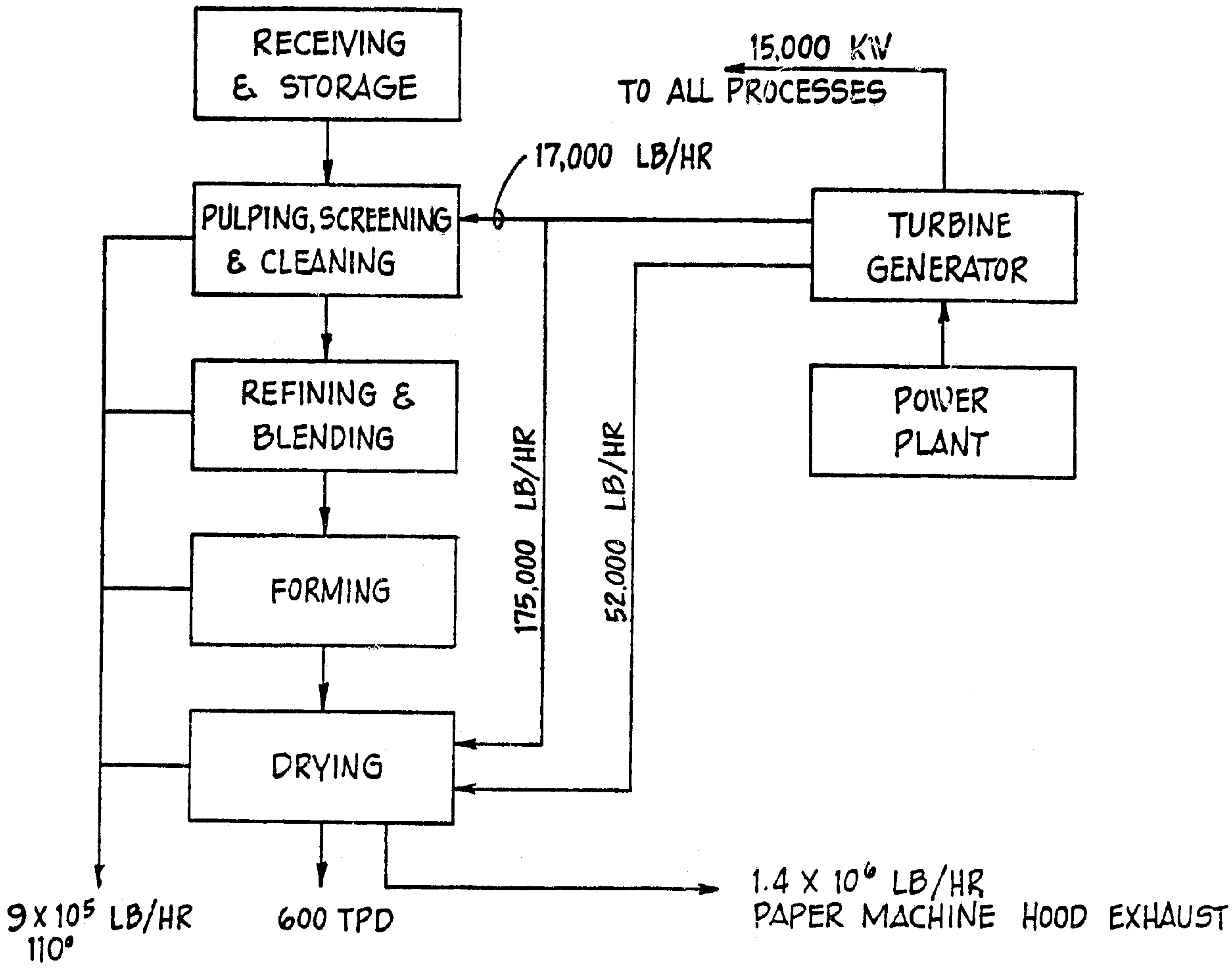
5.6.1 Input materials are wood, water, and coal. Product output is a variety of paper products, i.e. news print and coated book paper. Unit operations are chipping, pulping, washing, refining, forming, and drying. Major energy uses are chipping, pulping, refining, and drying. Power ties are maintained with the utility for backup in case of power failure. Some TMP pulping operations are cogenerators. The average energy consumption per unit of primary process output is 6.3 X 10^6 WH/ton and 23% of total operating costs are costs of energy.

5.6.2 The national capacity for the process is 5.4 X 10^6 tons/yr. The only major change anticipated in the industry is adaptation to coal as the primary fuel source. The growth trend anticipated is 3% per year. The anticipated total energy consumed by the process is 68 X 10^6 MWH/yr. The expected plant size in the period 1985 - 2000 is 400 TPD.

5.6.3 Plant kilowatt requirements average 31,300. KW steam requirements are 8,300 lb/hr @ 70 psig and 142,000 lb/hr @ 150 psig. Plant hours of operation are 8400 hr/yr. Large horsepower loads include, paper machine drive with 5-900 Hp and 8-600 Hp motors, primary refiners 6-5000 Hp, secondary refiner 6-4000 Hp, and fan pumps 1-600 and 1-700. Waste heat streams are pulp and paper mill sewer 1.7 X 10^6 lb/hr @ 120° F. and paper machine hood exhaust 6 x 10^5 lb/hr @ 240° F. It would not be practical to recover heat from the pulp and paper mill sewers. Heat can be recovered from the paper machine hood exhaust down to 160° F. The primary fuel is coal.

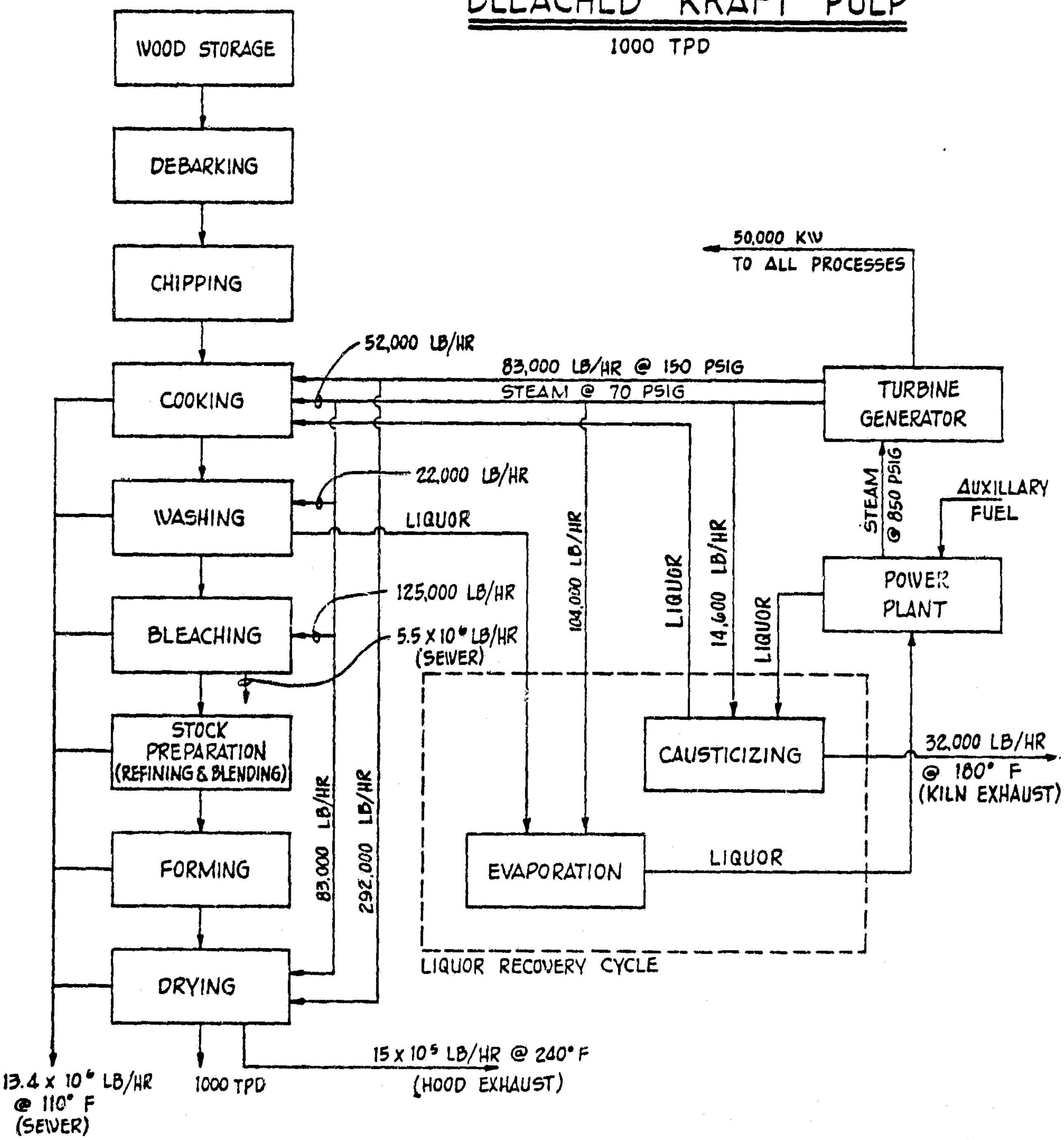
Thermal and electrical load profiles are straight line because of continuous operation.

WASTEPAPER - 600 TPD - UNBLEACHED



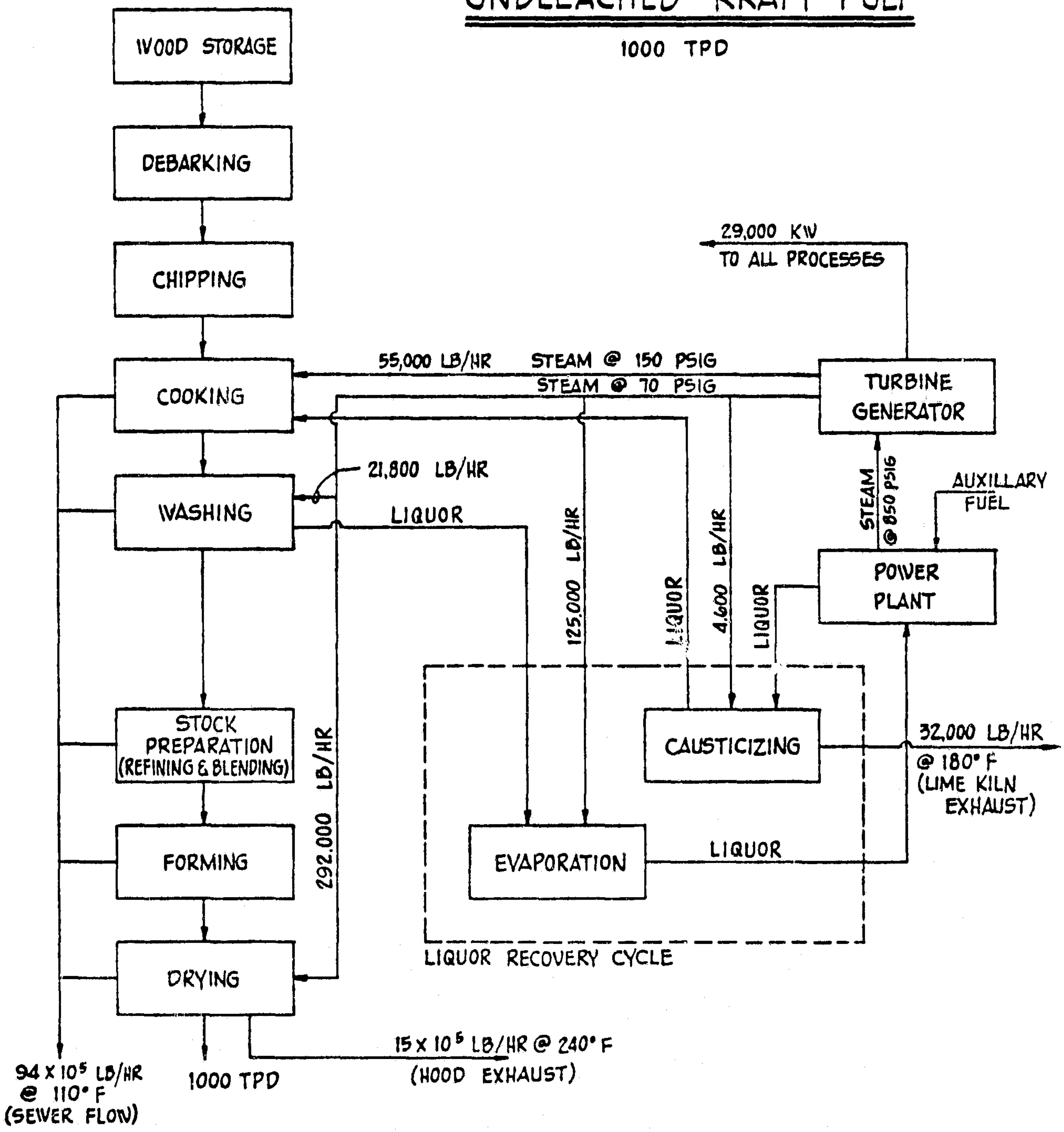
BLEACHED KRAFT PULP

1000 TPD



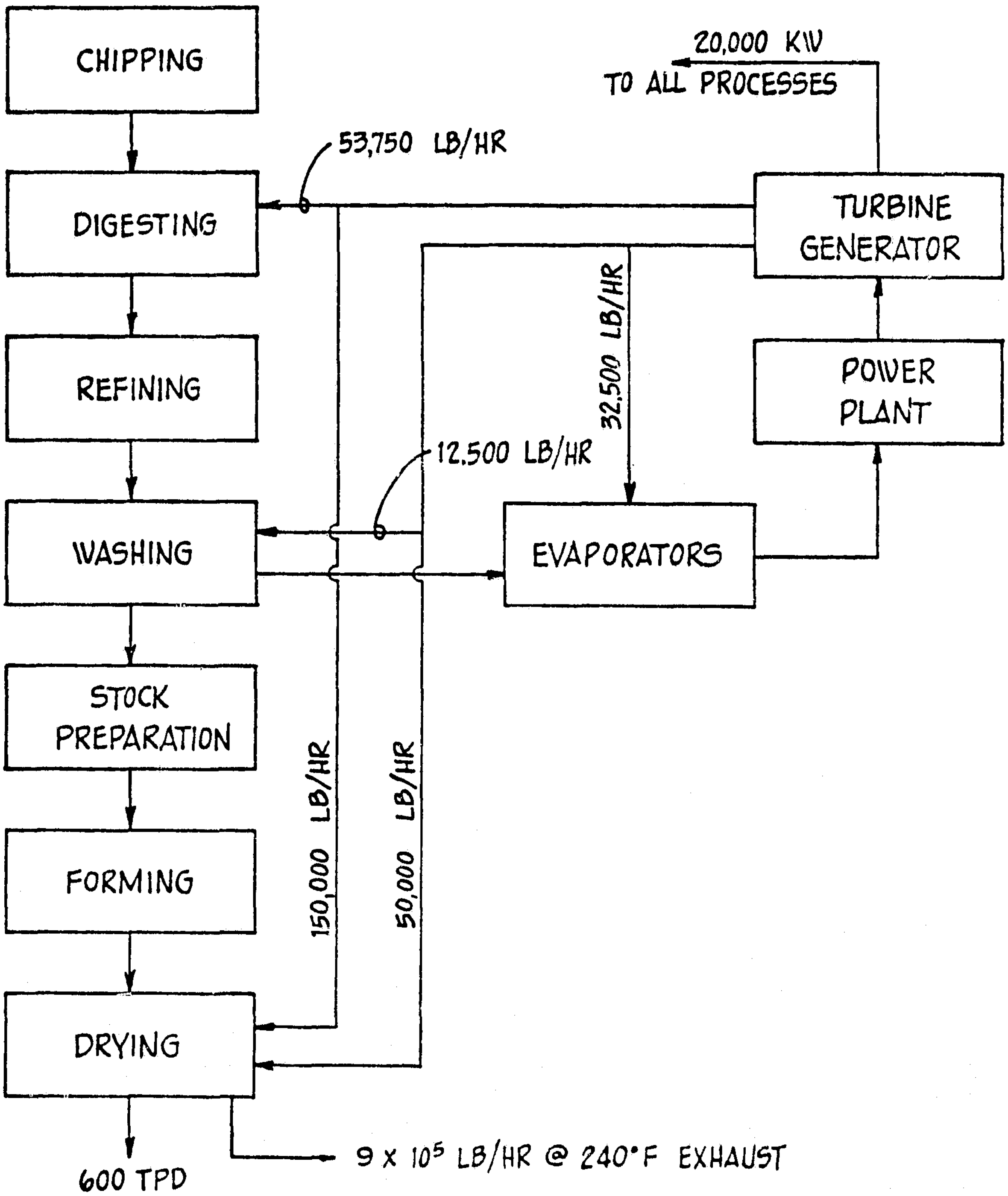
UNBLEACHED KRAFT PULP

1000 TPD

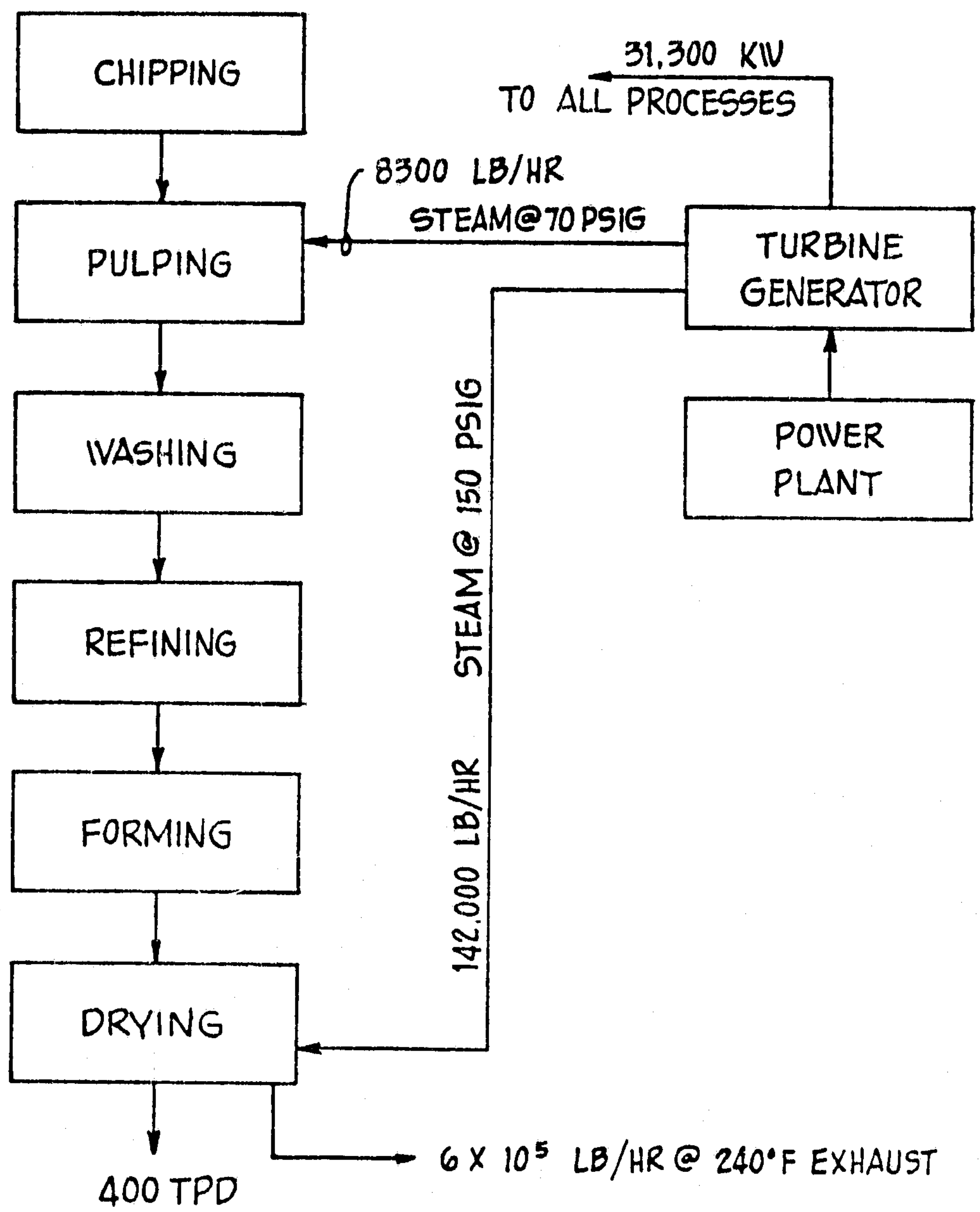


NEUTRAL - SULFITE SEMICHEMICAL

600 TPD



THERMO-MECHANICAL PULPING
400 TPD



CTAS Plant Data Sheet

A. Plant Name/Size: BLEACHED KRAFT/1000TPD (2621-2)

B. Products:

Product	lb/yr, etc.
Tissue	
Fine Paper	
Bleached Liner Board	

C. Plant Kilowatt Requirements: Average 50,000 kW; Peak 58,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
4×10^5	@	70	70%	316°F
3.8×10^5	@	150	70%	365°F
	@			

E. Other Heat to Process (Describe):

Oil fired lime kiln @135 x 10^6 BTU/HR.

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Description	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Paper Machine Drive	2@2500 HP 5@1400 HP	2@2900 HP 5@1600 HP	Variable	300-1200RPM	Motor
Kiln Draft Fan Drive	800 HP	900 HP	1800	Constant	Motor
Fan Pump Drive	3000 HP	3500 HP	1200	Constant	Motor

H. Operational Considerations:

Continuous Operation.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(Air)	15×10^5	240°F	Paper Machine Hood Exhaust
(Air)	32,000 lb/hr.	180°F	Lime Kiln Exhaust
(Water)	5.5×10^6 lb/hr.	90°F	Chlorinator Sewer

CTAS Plant Data Sheet

Plant Name/Size: Bleached Kraft/1000 TPD (2621-2)

J. Fuels: Primary Fuel Coal / 468 mil. Btu/hr (HHV)

Secondary Fuel Oil / 135 mil. Btu/hr (HHV)

By-product Fuel Bark & Black Liquid / 464 mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
30	Across the U.S.A.	All mills will be cogenerators

M. Application Discussion:

The Kraft process depends on burning of by-products and cogeneration to be economically feasible.

N. Preferred Economic Criteria: Discounted Rate of Return

O. Economic Discussion:

The expected return on investment is 17%.

P. Duty Cycle and Maintenance Philosophy:

The plant operates for 8400 hrs/yr. with biannual one week shutdowns for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Bleached Kraft/1000 TPD (2621-2)

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$\$48.9 \times 10^9$

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Not a new process.

T. What is the national capacity for producing this product

Now in 1978 14×10^6 tons/year

In 2000 25×10^6 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

We anticipate a growth rate of 3% a year in this time period.

W. National energy consumed by this process

In 1978 ______

In 1985 ______

In 2000 ______

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The typical size of a plant is now 300 TPD. The typical size built in 2000 will be 1000 TPD.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. Chipping, cooking, washing, bleaching, refining, blending, forming and drying. Major consumers are cooking, refining & bleaching.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion. 7%

Based on $400/ton and $35/ton coal $0.03/KWHR.

CTAS Plant Data Sheet

A. Plant Name/Size: Unbleached Kraft/1000 TPD

B. Products:

Product	lb/yr, etc.
Liner	
Bags	

C. Plant Kilowatt Requirements: Average 29,000 kW; Peak 33,500 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
4.7×10^5	@	70	70%	316°F
1.4×10^5	@	150	70%	365°F
	@			

E. Other Heat to Process (Describe):

Oil fired lime kiln @135 x 10^6 BTU/HR.

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Description	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Paper Machine Dr.	2@2200 5@1200	2@2500 5@1300	Variable	300-1200RPM	Motor
Kiln Draft Fan Dr.	600 HP	800 HP	1800	Constant	Motor
Fan Pump Drive	1000 HP	1200 HP	1200	Constant	Motor

H. Operational Considerations:

Continuous Operation.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(Air)	15×10^5	240°F	Paper Machine Hood Exhaust
(Water)	94×10^5	110°F	Paper and Pulpmill Sewers
(Air)	32,000 LB/HR	180°F	Lime Kiln Exhaust

CTAS Plant Data Sheet

Plant Name/Size: Unbleached Kraft/1000 TPD (2621-4)

J. Fuels: Primary Fuel Coal / 352 mil. Btu/hr (HHV)

Secondary Fuel Oil (Kiln) / 135 mil. Btu/hr (HHV)

By-product Fuel Bark-Black Liq / 341 mil. Btu/hr (HHV)

K. Fuels Discussion:

Coal will provide the bulk of the energy required. Oil will be used in process systems that will be direct fired.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
40	Across the U.S.A.	All plants will be cogenerators

M. Application Discussion:

The Kraft process depends on burning of by products and cogeneration to be economically practical.

N. Preferred Economic Criteria: Discounted Rate of Return

O. Economic Discussion:

The expected return on investment is 17%.

P. Duty Cycle and Maintenance Philosophy:

The plant operates for 8400 hrs/yr. with biannual one week shutdowns for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Unbleached Kraft (2621-4)

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$33.6 x 10^9

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 18 x 10^6 tons/year

In 2000 40 x 10^6 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

We anticipate a growth rate of 3% a year in this time period.

W. National energy consumed by this process

In 1978 __________

In 1985 __________

In 2000 __________

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The typical size of a plant is now 500 TPD. The typical size built in 1985-2000 will be 1000 TPD.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. Chipping, cooking, washing, refining, blending, forming and drying. Major consumers are cooking, refining and drying.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion. 7%

Based on $250/ron board, $35/ton coal and $0.03/KWHR.

Revised-August 30, 1978

CTAS Plant Data Sheet

A. Plant Name/Size: Neutral Sulfite Semichemical 600 TPD

B. Products:

Product	lb/yr, etc.
Corrugating Medium	

C. Plant Kilowatt Requirements: Average 20,000 kW; Peak 23,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
95,000	@	50	70	297°F
212,000	@	150	70	365°F
	@			

E. Other Heat to Process (Describe):
None

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Description	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Paper Machine Drive	2@2000 HP 5@1000 HP	2@2300 5@1500	Variable	300-1200	Motor
Fan Pump Drive	600 HP	690 HP	1200	Constant	Motor or turbine

H. Operational Considerations:

Continuous Operation.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(Water)	4.8×10^6	110°F	Pulp and Paper Mill Sewer
(Steam)	9×10^5 lb/Hr.	240°F	Paper Machine Hood Exhaust

<u>CTAS Plant Data Sheet</u>

Plant Name/Size: Neutral Sulfite 600 TPD (2621-6)

J. Fuels: Primary Fuel Coal / 405 mil. Btu/hr (HHV)
Secondary Fuel - / - mil. Btu/hr (HHV)
By-product Fuel - / - mil. Btu/hr (HHV)

K. Fuels Discussion:

Coal projected to be the primary fuel in 1985-2000.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
8	Across the U.S.A.	Good

M. Application Discussion:

Cogeneration exists in most mills and is more attractive when waste liquor can be cross-recovered in a Kraft recovery boiler.

N. Preferred Economic Criteria: Discounted Rate of Return

O. Economic Discussion:

The expected return on investment is 17%.

P. Duty Cycle and Maintenance Philosophy:

The plant operates for 8400 hrs/hr. with biannual one week shutdowns for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: NSSC 600 TPD (2621-6)

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$\$7.8 \times 10^6$

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Not a new process.

T. What is the national capacity for producing this product

Now in 1978 4.4×10^6

In 2000 8.4×10^6

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period) We anticipate a growth rate of 3% a year in this time period.

W. National energy consumed by this process

In 1978 ______

In 1985 ______

In 2000 ______

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The typical plant size is now 250 TPD and is expected to be 600 TPD.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. Chipping, digesting, refining, washing, forming, drying, major users of energy are digesting, refining, and drying.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion. 17%

based on \$310/ton pulp and \$35/ton coal and \$0.03/KWHR.

Revised-August 29, 1978
Revised-September 7, 1978

CTAS Plant Data Sheet

A. Plant Name/Size: Thermo-Mechanical Pulping - 400 TPD

B. Products:

Product	lb/yr, etc.
Newsprint	
Coated Book Paper	

C. Plant Kilowatt Requirements: Average 31,300 kW; Peak 36,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
8,300	@	70	70%	316°F
142,000	@	150	70%	365°F
	@			

E. Other Heat to Process (Describe):
None of Significance

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Description	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Primary Refiner	6@ 5000	5800	1800 RPM	-	Motor
Secondary Refiner	6@ 4000	4600	1800 RPM	-	Motor
Fan Pumps	1@ 600 1@ 700	690 800	1200 RPM	-	Motor
Paper Machine Drive	5@ 900 8@ 600	1035 690	Variable	300-1200	Motor

H. Operational Considerations:

Continuous Operation.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(Water)	1.7×10^6	120°F	Pulp and Paper Mill Sewer
(Steam)	6×10^5 lb/Hr.	240°F	Paper Machine Hood Exhaust

CTAS Plant Data Sheet

Plant Name/Size: TMP/400 TPD (2621-7)

J. Fuels:

Primary Fuel	Coal	264	mil. Btu/hr (HHV)
Secondary Fuel	-	-	mil. Btu/hr (HHV)
By-product Fuel	-	-	mil. Btu/hr (HHV)

K. Fuels Discussion:

Coal is the primary fuel projected to be used. Wood is assumed to be received in chip form with no bark recovery available.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
27	Across the U.S.A.	Good or Existing

M. Application Discussion:

Most Mechanical Pulp Mills have cogenerative systems.

N. Preferred Economic Criteria: Discounted Rate of Return

O. Economic Discussion:

The expected return on investment is 17%.

P. Duty Cycle and Maintenance Philosophy:

The plant operates for 8400 hrs/yr. with biannual one week shutdowns for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: TMP/400 TPD (2621-7)

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$\$10.7 \times 10^6$

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process. Not a new process.

T. What is the national capacity for producing this product

Now in 1978 5.4×10^6

In 2000 10.3×10^6

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period) We anticipate a growth rate of 3% a year in this time period.

W. National energy consumed by this process

In 1978 ________

In 1985 ________

In 2000 ________

X. Describe the typical size of this plant today and how that will change in 1985-2000. Typical plant size is now 250 TPD and expected to be 400 TPD.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. Chipping, pulping, washing, refining, forming, drying. Major users are pulping, refining and drying.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion. 23%

Based on \$400/ton Pulp - \$35/ton coal - \$0.03/KWHR.

CTAS Plant Data Sheet

A. Plant Name/Size: Wastepaper/600 Tons/Day (2621-8)

B. Products:

Product	lb/yr, etc.
Tissue	
Boxboard	

C. Plant Kilowatt Requirements: Average 15,000 kW; Peak 17,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
52,000	@	70	70%	316°F
192,000	@	150	70%	365°F
	@			

E. Other Heat to Process (Describe):

None

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Description	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Fan Pump Drive	600 HP	700 HP	Variable	300-1200RPM	Motor
Paper Machine Drive	2@1300HP	1500 HP	Variable	300-1200RPM	Motor
	5@ 700HP	800 HP			

H. Operational Considerations:

Continuous Operation.

I. Waste Heat Streams:

	lb/hr	Temp.	Description
(Water)	9×10^5 lb/hr.	110°F	Paper Machine Overflow to Sewer
(Air)	1.4×10^6 lb/hr.	240°F	Paper Machine Hood Exhaust

CTAS Plant Data Sheet

Plant Name/Size: Wastepaper/600 TPD (2621-8)

J. Fuels:

Primary Fuel	Coal	292	mil. Btu/hr (HHV)
Secondary Fuel	None	0	mil. Btu/hr (HHV)
By-product Fuel	None	0	mil. Btu/hr (HHV)

K. Fuels Discussion:

Coal projected to be the primary fuel in all plants.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
55	Across the U.S.A.	Good

M. Application Discussion:

Some wastepaper mills are now cogenerators.

N. Preferred Economic Criteria: Discounted Rate of Return

O. Economic Discussion:

The expected return on investment is 17%.

P. Duty Cycle and Maintenance Philosophy:

The plant operates for 8400 hrs/yr. with biannual one week shutdowns for maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Wastepaper/600 TPD (2621-8)

R. Describe the level of capital investment in this industry. (1985-2000 time period)
$26.3 x 10^9

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
Not a new process.

T. What is the national capacity for producing this product

Now in 1978 14×10^6 tons per year

In 2000 31.5×10^6 tons per year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No changes anticipated.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period) We anticipate a growth rate of 3% a year in this time period.

W. National energy consumed by this process

In 1978 ____________

In 1985 ____________

In 2000 ____________

X. Describe the typical size of this plant today and how that will change in 1985-2000. The typical size in 1978 is 250 TPD. We anticipate a typical size of 600 TPD in the years 1985-2000.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. Repupling, refining, blending, forming, and drying. The major energy consumers are refining and drying.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion. 12% based on a market price of $350/ton product, $35/ton coal and $0.03/KWH.

6.0 Chemicals & Allied Products

6.1 General

6.1.1 Process Considerations

Each major chemical product in the U.S. economy is made by one or more unique individual processes and there are many differences between the processes used in the manufacture of each product. There is, however, great similarity in the equipment used. Basically, the processes employ reactors where, in one or more steps, the feedstock material is chemically converted to the desired output product. Often the reactors contain a catalyst that is unique to the process. There will be associated process heaters (furnaces), heat exchangers, distillation columns, pumps, compressors, mixers, tanks, and sophisticated control systems to maintain automatically the temperature, pressures, and flow rates through the plant. The modern chemical plant represents a large capital investment, typically from 25 to 250 million dollars, and it is expected to operate continuously for weeks or months at near full capacity to meet fixed costs on the investment.

In this report we will describe the major features and energy using characteristics of the processes by which 18 of the major chemical products together with some of their by-products are produced in the United States. These products are all in the top 50 volume chemicals and account for approximately one-third of total energy use in the chemical industry. Production

of these chemicals generally occurs in large-volume chemical complexes. Each of these complexes is different depending on the particular characteristics of the company operating the installation. Variables affecting the type of operations integrated in a given complex include the raw material and fuel availability, the patent protection for the processes used, the marketing strengths of the company and many other factors. Presented below are some observations that might be considered relative to the process/plants described in this report and their potential for integration within a chemical production complex.

Light olefin (ethylene propylene) plants are almost always integrated with other plants that use these olefins. Most frequently an ethylene producing unit will be associated with polyethylene plants. Plants producing vinyl chloride, ethylbenzene and ethanol use ethylene as a feedstock and will frequently be found in the same complex with an ethylene plant. Ethylbenzene and styrene plants are often integrated. Plants, such as a cumene plant or an isopropanol plant, which use propylene for a feedstock are often co-located with the light olefin plant producing the propylene. Chlorine-caustic soda plants are frequently integrated with units such as a vinyl chloride plant which require chlorine as a starting material. Cumene and phenol plants will often be found together. In the future, oxygen plants will be integrated with many plants that now use air for oxidation reactions, thus eliminating nitrogen and improving the economics for recovery and use of the vent gases.

Conversely, it is also possible to find plants such as those listed above, which are not integrated. In the large concentrated chemical processing centers, such as the Houston Ship Channel or the Mississippi River between Baton Rouge and New Orleans, a plant using ethylene for feedstock may be supplied via pipeline from an ethylene producer miles away. There also are some processes/plants which are inherently independent and will be found most often as "stand-alone" units. These include ammonia, phosphoric acid and synthetic fiber plant.

It appears from present trends that future growth in production of the major chemical products will occur primarily at existing sites. However, expansion of production capacity will usually consist of the building and operation of complete processing plants for the particular product concerned. These plants will be dependent upon the parent complex for such items as steam, fuel, electricity and cooling water and possibly for their feedstock supply as well as for product disposal. Since steam production is so frequently centralized in a chemical complex, the final section of this report describes typical chemical industry steam generation plants of the future. It is worth noting that increasingly the trend is to have individual plants within a complex eliminate the harmful materials from their own effluents rather than have the complex install or increase their waste disposal capacity for this purpose.

6.1.2 Economic Considerations

Production of the chemicals chosen for discussion in this report is dominated by large sophisticated national and international corporations. These corporations use the latest and most advanced economic evaluation techniques such as cash flow analysis, net present value, and discounted rate of return. These techniques are used as a basis for calculating return on investment (ROI) which is the prinicpal criterion influencing investment decisions. The precise method used will vary from one company to another.

In estimating the capital investment for a particular sector of the chemical industry we have converted all asset values to 1976 replacement values. Projections of future investments are also in terms of 1976 dollars without escalation.

In the determination of energy costs as a fraction of total production cost, we have used certain standard assumptions throughout this section of the report. These assumptions are listed below. All cost and prices are typical 1976 values.

Utilities costs: Steam - $2.40 per 1000 pounds; Electricity - 17.5 mils per kwh; Fuel - $2.00 per million BTU's; Cooling Water - $.03 per 1000 gallons.

Operating Labor: $9.30 per hour; Supplies and Laboratory Services - 30% of operating labor; Plant Overhead - 80% of total labor.

Capital related costs: Taxes, insurance and depreciation - 12% of total fixed capital.

6.2 Light Olefins from Cracking Fuel Oils

This process and product belongs to Industry 2869 Industrial Organic Chemicals. The total investment in this industry is $24 billion. The investment in plants for the production of light olefins is over $5 billion making this the largest single sector of the industrial organic chemicals industry.

6.2.1 Process Description

Feedstock for this plant is gas oil. Alternate feedstocks for light olefin production could be naphtha or gases such as propane and ethane. With a gas oil feed a wider range of products is produced. The major product output will be ethylene. The next most significant product will be propylene followed by butadiene. These olefins will account for approximately 44% of the process output. The remaining output will be gasoline material, fuel oils and fuel gases. The plant will have a feed input of 5900 tons per day of gas oil, and will produce 1510 tons per day of ethylene, 860 tons per day propylene, 240 tons per day butadiene and 2580 tons per day of fuel oils including the gasoline.

The major energy-using operations in this plant are the cracking furnaces and the gas compressors. Other unit operations are distillation for separation of the products, and pumps for product movement throughout the plant. The cracking furnaces are designed for high thermal efficiency. These furnaces will operate on the fuel oils and gases produced within the process. They heat the steam and gas oil feed mixture to cracking temperatures, superheat the steam, and finally heat the boiler feedwater for the steam, achieving thereby more than 85% thermal efficiency.

The heat put into the process by the cracking furnaces is extracted from the products with waste heat boilers. The steam derived from these waste heat boilers is used elsewhere in the process both for diluent steam in the feed mixture and for reboiler operations in the distilling columns. Steam is also used to operate the gas compression turbines. Steam is used at several different pressure levels from 1500 psig to 35 psig. At the higher level (1500 psig) external steam input is required in the amount of 150,000 pounds per hour. At the lower steam level (35 psig) surplus steam is produced in the amount of 44,000 pounds per hour. Since steam is used for most of the shaft power requirements in this plant, relatively little electrical input is required. The electrical input is 5700 kilowatts. However, since this electricity is used in control systems and other critical components, it is necessary that it have a high reliability or that an alternate electrical source be available for emergencies.

This process is designed to have a high level of energy recovery and also to have a high operational reliability. Consequently, although it is feasible that alternative energy conversion technologies could be incorporated into the design of this plant to enhance the cogeneration potential, extensive testing and demonstration would be necessary before commercial acceptability would be had.

Light olefin production appears to have a high energy intensity. This plant requires 32 million BTU per ton of ethylene produced. However, when the energy is allocated to all products produced, the intensity is comparable to that of other organic chemicals. The cost of energy for fuel and power represents 15% of the total operating cost.

6.2.2 Production Considerations

Although this process is relatively new, it is expected that it will become the principal process for the production of ethylene and propylene in future years. At the present time, the national capacity for production of ethylene is 12 million tons per year. It is expected that this will increase by the year 2000 to approximately 48 million tons per year. Ethylene and propylene are widely used as chemical feedstocks for many other chemical and plastic products. The products derived from ethylene and propylene are in growing demand. The growth has been averaging more than 8% per year and, although

this will taper off somewhat in future years, production is still expected to quadruple by 2000.

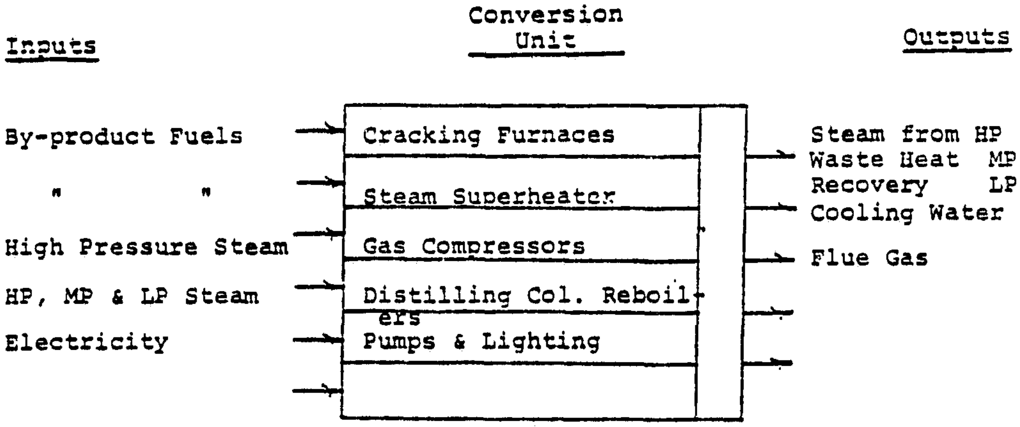
The average production level for present ethylene plants is about 950 tons per day product. New plants are being built in sizes from 750 tons per day to 2000 tons per day. It is expected that the future typical plant size will be 1500 tons per day (1 billion pounds per year). Economies of scale above this level are very debatable.

The plant described here has all features (waste treatment, waste heat recovery, etc.) necessary to comply with regulatory requirements and energy economics for the foreseeable future. The plant is designed to use the feedstocks expected to be available in this future period.

At the present time, approximately 300 trillion BTU per year of net energy input (fuel and power) is used in the production of ethylene. It is projected that this will increase to 750 trillion BTU per year in 1985 and 1.1 quadrillion BTU in the year 2000.

6.2.3 Energy Characteristics

Energy Schematic:



Electricity Requirements: Average 5700 KW; Peak +5-10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
150,000	1500	0	--

Other Heat to Process:
(Recovered from the process and used internally)
By-product fuel = 1900 x 10^6 Btu/hr

Steam: 123,000 lb/hr at 600 psig
581,000 " " 150 "
428,000 " " 75 "
128,000 " " 35 "

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
38,000	Gas Compression 0-100 psig	Steam
37,000	" " 0-250 psig	"
5,800	" " 0-212 psig	"

Waste Heat Streams:

lb/hr	Temp.	Description
44,000	260°F	35 psig Steam
2.5 x 10^6	350°F	Flue Gas
38 x 10^6	100-120°F	Cooling Water

Fuels:

Primary Fuel	(By-Product Fuel) /	(see below)	MM BTU/hr
Secondary Fuel	High Pressure Steam /	175	MM BTU/hr
By-Product Fuel	Gas and Oil /	1900	MM BTU/hr

6.3 Vinyl Chloride Monomer from the Balanced Chlorination and Oxychlorination Process

This product and process also belong to the Industrial Organic Chemicals Industry SIC #2869. As indicated in the preceding section, this industry has approximately $24 billion of investment. The vinyl chloride monomer production facilities represents over $600 million of this investment at 1976 replacement costs.

6.3.1 General Process Description

This plant starts with ethylene and chlorine as the principal feed materials and produces 1000 tons per day of vinyl chloride. The plant has the following unit operations:

- Cracking furnace
- Distilling columns
- Air compression
- Heat recovery boiler
- Pumps
- Reactors

The principal energy use is the fuel to the cracking furnace and the steam for the distilling columns. Somewhat smaller energy use is the electricity to the air compressor. The remaining unit operations use smaller amounts of energy. This process, like other organic chemical industry processes, handles highly volatile and flammable products and requires that careful procedures be followed when starting up and shutting down. Consequently, power failures are very critical and must be kept to a minimum.

It is feasible that topping systems for power generation could be used in connection with both the direct heat and the steam required in this process. However, it would likely be necessary to redesign major components of the plant to incorporate such features.

Total average energy consumption in this plant is approximately 16 million BTU per ton of vinyl chloride produced. Based on the assumptions pertaining to operating costs that were presented at the beginning of this discussion, energy costs in the vinyl chloride plant represent 13% of total operating cost.

6.3.2 Production Characteristics

The present national capacity for production of vinyl chloride is approximately 3 million tons per year. Two-thirds of this production is from the process described here.

No major process changes are contemplated during the next several years, however, as environmental requirements become more stringent, new plants will likely use pure oxygen in the oxychlorination reaction in place of air. This will reduce the vent gas flow and permit recovery of the small amounts of ethylene lost in the vent gas.

Affect on the overall plant energy input will be small. Since ethylene can be produced from a number of different hydrocarbon sources, as mentioned previously, and since there is no contemplated shortage of chlorine in the foreseeable

future, this plant should have no need to change raw materials or to change the process because of raw material shortages.

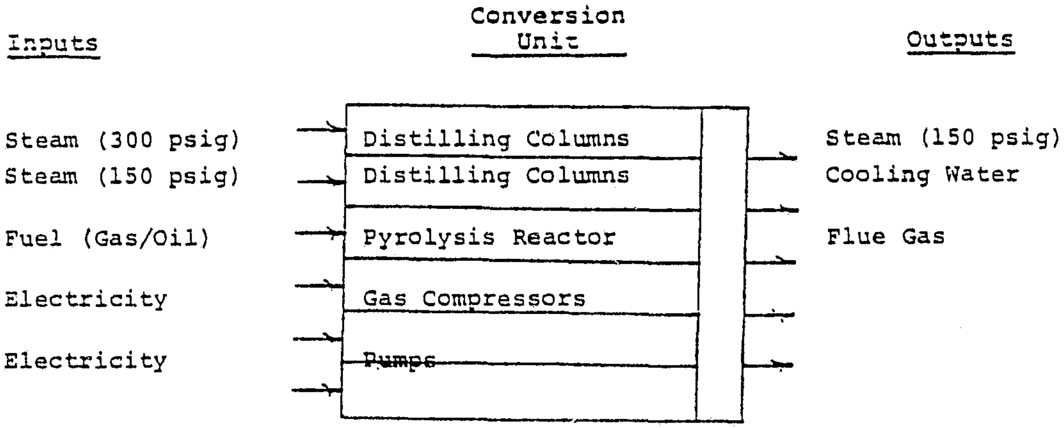
Vinyl chloride is used almost entirely (97%) in various types of polymers for plastic products. It is used as PVC in a variety of products from shoe soles to plumbing systems. It is replacing many other products in common use and has been growing in production more than 10% per year. Demand will quadruple by the year 2000.

In the period from now until 2000 vinyl chloride plants will improve their energy efficiency. Thus, although production will quadruple, energy consumption in 2000 is expected to be about 160 trillion BTU per year which is approximately triple the present energy use of 50 trillion BTU per year for this product. Energy consumption in 1985 is estimated to be 110 trillion BTU per year.

The average size of existing vinyl chloride monomer plants today is just over 700 tons per day production. One plant is more than 1000 tons per day. Future typical plant size is expected to be approximately 1000 tons per day as there appears to be little or no economy of scale above this level.

6.3.3 Energy Characteristics

Energy Schematic:



Electricity Requirements: Average 4000 KW; Peak +5-10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
180,000	150	Condensate	200-300°F
27,000	300	"	300-320°F

Other Heat to Process: The primary energy input to this process is the fuel (oil or gas) to the cracking (pyrolysis) furnace. Amount = 480 MM Btu/hr.

Hours of Operation at Average Conditions: 8300 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
1500	Refrigeration	Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
15×10^6	100-120°F	Cooling Water
0.7×10^6	400°F	Flue Gas
56×10^3	330°F	100 psig Steam

Fuels:

Primary Fuel Gas or Oil / 480 MM BTU/hr

Secondary Fuel / MM BTU/hr

By-Product Fuel / MM BTU/hr

6.4 Styrene Monomer Production by the Dehydrogenation of Ethylbenzene

This product and process also belong to the Industrial Organic Chemicals Industry SIC #2869. The capital investment in styrene monomer production is over $400 million. This represents less than 2% of total investment in the industrial organic chemicals industry.

6.4.1 General Process Description

This plant uses ethylbenzene as the primary feedstock. The ethylbenzene is dehydrogenated to produce 1500 tons per day of styrene monomer. In addition to the styrene monomer, small amounts of by-products are formed. These amount to 70 tons per day of toluene, 60 tons per day of benzene, and 90 tons per day of hydrocarbon fuels.

This plant uses a relatively simple chemical process. Unit operations consist of a process heater to superheat steam, a reactor containing catalyst for the dehydrogenation reaction, distillation to separate the products and a compressor to recover fuel gas for reuse. Waste heat in the process is removed in air-cooled and water-cooled condensers.

The major energy use in this plant is the steam which is used both as a feed material to the reactor, and is also used for heat in the distillation columns. The next most significant energy use is the fuel to the process heater which superheats the steam. A smaller but significant

amount of energy is used by the fuel gas compressor. Other energy uses are small and distributed through the plant.

This plant, like most of the other major processes in the organic chemicals industry, is designed for continuous, around-the-clock, seven-day-per-week operation, and is not easily started up or shut down. Consequently, power supply interruptions would have serious adverse affects if they occurred more than rarely.

Because this plant uses a large quantity of steam together with a significant amount of electrical power, it is feasible that the cogeneration of steam and electricity would have application here. However, modification of the process to incorporate advanced energy conversion technologies would necessitate very substantial testing and demonstration prior to commercial acceptance.

The average energy consumption in this plant is 9.7 million BTU per ton of styrene monomer produced. Again, using the basic assumptions for operating costs described earlier, the energy cost in this process represents 6.5% of total operating cost.

6.4.2 Production Characteristics

The national capacity for production of styrene is approximately 3.5 million tons per year. Essentially all of this capacity utilizes the ethylbenzene dehydrogenation process. This

process has no environmental hazards and no significant changes will be required to meet expected environmental requirements. There likely will be additional heat recovery incorporated into the process as time proceeds, however the energy use shown here should be typical for the 1985-2000 time period.

Styrene is used in a wide variety of plastics and elastomers. End products vary from automobile tires to building insulation and these products have a fast growing demand. The use of styrene is expected to triple by 2000.

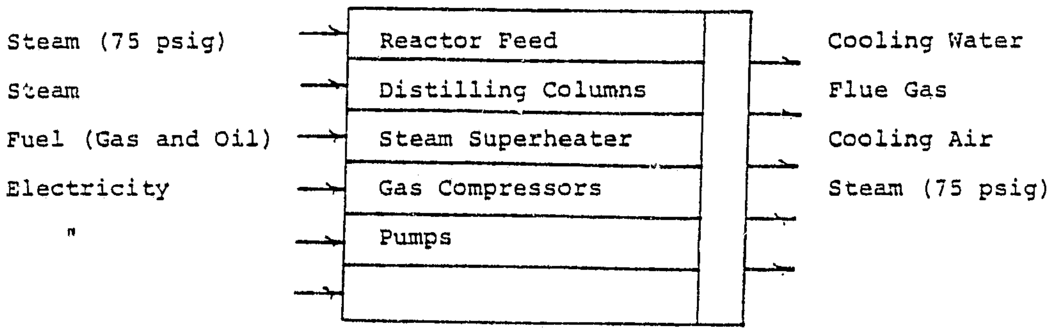
In 1978, styrene monomer plants consumed an estimated 35 trillion BTU of energy for fuel and power. This is expected to increase to 65 trillion BTU in 1985 and to 90 trillion BTU by the year 2000.

There are 13 styrene monomer plants in production in the U.S. at the present time. Average plant size is 950 tons per day. One plant is approximately 2000 tons per day. Based on economies of scale and maintenance difficulties associated with increasingly larger plants, it is expected that new plants constructed in the 1985-2000 time period will average about 1500 tons per day.

6.4.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs



Electricity Requirements: Average 4400 KW; Peak +5-10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
320,000 (net)	75	Condensate	190°F
190,000	30	Condensate	250°F

Other Heat to Process: By-product fuel (approx. 200 MM Btu/hr) is produced and consumed in this process. In addition, a small amount (16 MM Btu/hr) of direct fuel (oil or gas) input is required.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
2700		Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
8×10^6	100-120°F	Cooling Water
0.3×10^6	400°F	Flue Gas
0.66×10^6	150-240°F	Air Cooling

Fuels:

Primary Fuel	Oil/Gas	/ 16	MM BTU/hr
Secondary Fuel		/	MM BTU/hr
By-Product Fuel	Hydrogen and Waste Oils	/ 200+	MM BTU/hr

6.5 Ethylbenzene from the Vapor Phase Alkalation of Benzene

This pr~duct and process also belong to the Industrial ~rganic Chemicals Industry SIC #2869. The capital investment in ethylbenzene production is approximately $150 million. This represents less than 1% of total investment in the Industrial Organic Chemicals Industry.

6.5.1 General Process Description

This process uses benzene and ethylene as feedstock and produces 1700 tons per day of ethylbenzene. This is a relatively simple process with only a few unit operations. The major units in the plant are the process heater for vaporizing feedstock, the reaction vessel containing catalyst, the condensers, and the distillation unit. The major energy inputs to this process are fuel to the heater for feedstock vaporization and fuel for heat to the reboilers of the distilling columns. Waste heat is obtained from the condensers on the reactor product and also from the reflux condensers on the distilling columns.

This plant is a single train unit designed to operate continuously 24 hours per day, seven days per week. It is not designed to have frequent startups and shutdowns. Consequently, a power failure creates serious difficulties in plant operation and the reliability of the power supply is an important consideration.

This plant represents the state of the art, and incorporates substantial waste heat recovery. The plant has no particularly harmful effluents

to require special treatment. Future regulations may require special precautions in handling benzene, however, these should have little effect on energy use. The plant uses substantial quantities of steam and direct fuel input. However, in proportion, a relatively small amount of electrical power is required. It is therefore assumed that cogeneration technology installed in this plant would produce excess electricity beyond the needs of the plant. It is feasible that by redesign of the energy conversion equipment electricity could be produced from topping the fuel and/or steam input to this plant.

Combined energy input to this plant is 5.5 million BTU per ton of ethylbenzene. However, extensive energy recovery using waste heat boilers produces more than 4.5 million BTU per ton of product in steam for export from the plant. If the surplus steam is assumed to have no value, and if we make the same assumptions as previously regarding operating costs in this plant, then the cost of energy represents 5% of the production cost. Value assigned to the by-product steam will reduce this percentage accordingly.

6.5.2 Production Characteristics

The national capacity for production of ethylbenzene at the present time is 4.5 million tons per year. The vapor-phase alkalation process used in the plant described herein is relatively new and accounts for only a small part of this production. It is expected, however, that this

vapor-phase process, which has a lower production cost for the product, will be employed in the majority of new plants constructed in the future. Since this process represents the latest commercially available state of the art, little or no change is expected for plants which will be constructed in the next several years. The process and energy usage described herein should be applicable to plants constructed in the 1985 to 2000 time period.

Ethylbenzene is used almost entirely in the production of styrene and consequently will grow at the same rate as styrene production grows. Since styrene markets are very diverse and fast growing, ethylbenzene is expected to continue in large demand. Production of ethylbenzene will triple by 2000.

It is estimated that present production of ethylbenzene consumes 22 trillion BTU per year in the United States. Although there will be substantial growth in the use of ethylbenzene, increased utilization of the vapor-phase process with attendant increased heat recovery will result in only a modest increase in energy use. In 1985, total energy use is expected to be about 27 trillion BTU per year. By the year 2000, when most production will be from vapor-phase plants, gross energy use without credit for steam produced will be 65 trillion BTU per year. However, utilization of the surplus steam produced in these plants would reduce net energy consumption to 10 trillion BTU per year.

There are presently 12 major plants in the U.S. producing ethylbenzene. They range in size from 400 tons per day up to 2600 tons per day. Average size is 1200 tons per day. The most recent plant constructed has a throughput of 1700 tons per day and it is expected that this will be the nominal plant size for many years to come.

6.5.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
H.P. Steam (600 psig)	Distilling Columns	Condensate Water
Fuel (Gas or Oil)	Process Heater	Cooling Water
		M.P. Steam (150 psig)
		L.P. Steam (25 psig)
		Flue Gas

Electricity Requirements: Average 700 KW; Peak +5-10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
220,000	600	Condensate	---

Other Heat to Process: 140 MM Btu/hr from fuel gas or oil to the process heater which heats the benzene to the reactor (exit temperature = 780°F).

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver

Waste Heat Streams:

lb/hr	Temp.	Description
198,000	25 psig/240°F	Heat Recovery Steam
124,000	150 psig/360°F	" " "
245,000	100 - 120°F	Cooling Water
177,000	450°F	Flue Gas

Fuels:

Primary Fuel Oil/Gas / 140 MM BTU/hr

Secondary Fuel ______ / ______ MM BTU/hr

By-Product Fuel ______ / ______ MM BTU/hr

6.6 Phenol from the Cumene Peroxidation Process

This product and process belong to the Industrial Organic Chemical Industry SIC #2869. Production processes for phenol manufacture represent a capital investment of almost $400 million which is approximatly 1.5% of the total investment in the Industrial Organic Chemicals Industry.

6.6.1 General Process Description

Cumene is the primary feedstock for this process. The cumene is oxidized with air and the resulting intermediate product is chemically cleaved to form phenol and by-product acetone. The plant is sized to produce 600 tons per day of phenol. Accompanying this will be 380 tons per day of acetone and approximately 50 tons per day of tars which can be used for fuel.

This process consists of only a few basic operations. These are catalytic reaction, distillation, vacuum evaporation, gas compression and pumping. The major energy use occurs in the steam used in the reboilers of the distillation columns.

This process develops an intermediate product which is inherently unstable and if reaction conditions are not carefully controlled explosion could result. Consequently it is necessary that very reliable utilities be employed in this process so as to not cause serious fluctuations in the reactor temperatures and pressures.

A large amount of steam is consumed in this process, and it is feasible that topping systems used in conjunction with the steam could cogenerate electricity to provide the power needs of the plant. It is quite probable that excess electricity would be developed. The reactions in this process are exothermic and because of the necessity to carefully control reactor conditions heat is removed from the reactors with cooling water. It is possible that with sufficient developmental study advanced energy conversion technologies could utilize the excess heat produced in the reactors. However, it would be necessary to extensively prove the reliability and safety of such design modifications.

This plant requires an energy input of 14 million BTU per ton of phenol produced. At this level of use, the cost of energy represents 9% of the total production cost of the phenol.

6.6.2 Production Characteristics

The present production capacity for phenol in the U.S. is 1.5 million tons per year. Almost 90% of this production uses the cumene peroxidation process.

Phenol is a very undesirable material in water effluents and its presence is expected to be increasingly restricted in water discharges from chemical plants in the future. It is likely that the future phenol plant will have more equipment and energy use devoted to the removal of phenol

and other trace materials from the water effluents. This, however, should not effect energy use by more than a few percent.

The cumene raw material for this process is made from benzene and propylene, each of which are available from many sources and starting materials. It is not anticipated that cumene availability will have any effect upon phenol production in future years or the process by which phenol is produced.

Phenol is a versatile chemical used as an intermediate in the manufacture of other chemicals and also used in the manufacture of various resins for plastics. Three major phenol derivatives, epoxies, caprolactum, and polycarbonates have high-growth potential. The use of phenol is expected to triple by the year 2000.

The energy consumed in the production of phenol is 20 trillion BTU per year. This is expected to increase to 45 trillion BTU in 1985 and to 60 trillion in the year 2000.

There are 12 plants in the United States producing phenol at the present time. Capacities of these plants range from 100 tons per day to 800 tons per day. The most recently built plant has a capacity of 590 tons per day and it is expected that future plants will be in this same approximate size. The plant described herein is sized at 600 tons per day.

6.6.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
H.P. Steam (600 psig)	Distilling Column	Cooling Water
M.P. Steam (200 psig)	Distilling Columns	
Electricity	Air Compressor	
"	Pumps & Lighting	

Electricity Requirements: Average 6000 KW; Peak +5% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
30,000	600 psig	Condensate	
270,000	200	Condensate	

Other Heat to Process:

Hours of Operation at Average Conditions: 8200 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
3000	Air Compressor	Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
17×10^6	100 - 120°F	Cooling Water

Fuels:

Primary Fuel* _____ / _____ MM BTU/hr

Secondary Fuel _____ / _____ MM BTU/hr

By-Product Fuel _____ / _____ MM BTU/hr

*All heat input is provided by the steam.

6.7 Ethanol Synthesis from Ethylene and Water

This product and process also belong to the Industrial Organic Chemicals Industry SIC #2869. The investment in facilities to produce ethanol is presently approximately $275 million. This represents just over 1% of the total investment in the Industrial Organic Chemicals Industry.

6.7.1 General Process Description

This is a relatively simple catalytic process. Raw materials are ethylene and water. In the presence of a catalyst and under high pressure ethanol is directly produced. In addition to the 800 tons per day of manufactured produced in this plant, approximately 40 tons per day of miscellaneous hydrocarbon materials are produced, which can be used for fuel.

The unit operations in this process are feedstock superheating, catalytic reaction, gas compression, distillation and pumping. The major energy input to the process is the steam to the distillation operation. Condensate from this steam in turn is used for process water in the feed to the reactors. Oil or gas is used in appreciable amounts in the process heater to superheat the ethylene and water feed mixture. The bulk of the electricity usage occurs in the gas compressor. Other energy use is small and is widely distributed throughout the plant.

This plant is designed to operate on a 24 hour per day, 7 days per week continuous basis. Shutdowns are infrequent. The plant is not

designed to be started up or shut down on a frequent basis. Consequently, reliable utilities and power supply is essential to the economic operation of this plant.

Maximum temperature requirements in this process are in the range of 500° to 600°F. Therefore, it is feasible that topping systems could be installed on the fuel or steam systems to cogenerate electricity. Again, as discussed previously, modification of the design of this plant to incorporate cogeneration capability would require extensive development effort to insure reliability of the energy conversion components in long-term, continuous use.

Energy consumption in this process for fuel and power averages approximately 13.7 million BTU per ton of ethanol produced. Using the assumptions pertaining to operating costs previously discussed, the energy input to this process represents 13% of the total operating cost.

6.7.2 Production Characteristics

There exists at the present time in the United States, the capacity to produce 1 million tons per year of synthetic ethanol. In addition, there is a small amount of productive capacity utilizing fermentation processes starting with sugars or other natural materials. More than 90% of the synthetic ethanol is produced by the direct hydration of ethylene as described here.

This is a relatively simple catalytic process and few changes are expected in future years. No harmful effluents are produced and no additional equipment or energy use will be required to meet environmental requirements. Catalyst improvements can be expected to bring some decrease in the temperature or pressure required for the reaction which will bring a small reduction in energy use in future plants. The raw materials, ethylene and water, from which the ethanol is made, will be readily available throughout the foreseeable future and no change in feedstock is contemplated.

Ethanol is an old product which is widely used as a solvent in both industrial and consumer products and as an intermediate product in chemicals manufacturing. It has also been proposed as a synthetic liquid fuel to be blended with gasoline. If ethanol is incorporated into gasoline fuel, it will likely only occur as a result of some type of governmental mandate. In the absence of the use of ethanol in fuels, the demand for ethanol will grow at about the same rate as the general economy and can be expected to double by the year 2000.

There are six plants in the U.S. today making synthetic ethanol. The average plant size is 500 tons per day. One plant is much larger, producing over 1000 tons per day. This plant has grown incrementally, however, and it is expected that future new plant additions will average approximately 800 tons per day in size.

6.7.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Fuel (Oil or Gas)	Process Heater	Cooling Water
Steam (450 psig)	Distilling Columns	Flue Gas
Electricity	Gas Compressor	
"	Pumps & Lighting	

Electricity Requirements: Average 3300 KW; Peak +5% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
400,000	450	0	(Condensate is used for process water.)

Other Heat to Process: 65 MM Btu/hr from fuel gas or oil to the process heater to preheat the feed to the reactor.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
4000	Gas Compressor	Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
23×10^6	100 -- 120°F	Cooling Water
93×10^3	450°F	Flue Gas

Fuels:

Primary Fuel	Oil/Gas	/ 65	MM BTU/hr
Secondary Fuel		/	MM BTU/hr
By-Product Fuel	Heavy Oils	/ 58	MM BTU/hr

6.8 Cumene from Benzene Alkalation

This product and process belong to the Industrial Organic Chemicals Industry SIC #2869. Capital investment in cumene production facilities is approximately $125 million which is about .5% of total investment in the Industrial Organic Chemicals Industry.

6.8.1 General Process Description

Feed materials for this process are benzene, propylene and propane. The propane does not enter into the reaction, however, liquid propane is injected to the reactors to remove heat of reaction and prevent undesirable temperature increase. The propane is later separated from the reactor products and recycled. This plant produces 700 tons per day of cumene.

There are relatively few operations in this process. The major units are the feed process heater, the reactor, and the distillation columns. No steam is used in this process. Oil or gas is burned in a process heater to heat DOWTHERM*, which in turn is circulated to the process units to supply the necessary heat inputs for the distillation operation and the preheating of the feed materials.

This plant is a large single train operation designed to operate continuously 24 hours per day, 7 days per week and cannot be readily

*Trademark of The Dow Chemical Company

shutdown or started up. Consequently, reliability of utilities, particularly the power and steam supply to this plant, is a critical consideration.

The heat requirements for this process are at a relatively low temperature, in the range of 500°F and below. Consequently, the fuel and/or steam could be topped for electricity production by appropriate technology. In such case, as was discussed previously, it would be necessary to redesign some of the energy conversion equipment in this process and then have a thorough testing and demonstration in order to obtain commercial acceptance.

The energy required for this process is 4.3 million BTU per ton of cumene produced. This represents only the energy required for fuel and power and does not include feedstock to the process. This amount of fuel and power constitutes 3% of the total operating cost of the cumene plant.

6.8.2 Production Characteristics

The production capacity for cumene in the United States is 1.5 million tons per year. All of this production is from the benzene alkalation process. The benzene and propylene feedstocks are and will remain readily available and this process will not change in the future from a need to process alternate feedstocks.

There are no significant undesirable effluents from this process and the foreseeable future requirements for environmental protection should not have a notable effect on these plants. Perhaps the only expected change in the process will come as a consequence of higher energy prices which should result in improved heat recovery and heat utilization. However, this will have only a marginal impact on the energy requirements for this process.

Cumene is used almost entirely in the manufacture of phenol and acetone. Growth will parallel the growth of these two products. Both phenol and acetone, which are older, well-known, widely used products in the chemical industry, will grow at about the norm for the total chemical industry. This indicates that the use of cumene will be approximately tripled by the year 2000.

It is calculated that the production of cumene requires 6.5 trillion BTU per year in the United States. This is expected to increase to 10 trillion BTU in 1985 and to 15 trillion BTU in the year 2000.

The average size of cumene plant in the United States is 380 tons per day. The plants range from 150 tons per day up to 1000 tons per day. Although there are two plants in the 1000 tons per day size, these plants have grown incrementally and it is expected that future plant construction will be sized at approximately 700 tons per day nominal throughput for cumene.

6. 8.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Fuel (Gas or Oil)	Process Heater	Hot Dowtherm (450°F)
Hot Dowtherm	Feedstock Heat Exchanger	Cooling Water
Hot Dowtherm	Distilling Columns	Flue Gas
Electricity	Pumps & Lighting	

Electricity Requirements: Average 600 KW; Peak ______ KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns

Other Heat to Process: Fuel (gas or oil) -- 110 MM Btu/hr to a process heater to heat circulating Dowtherm®.

Hours of Operation at Average Conditions: 8400 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
---		

ste Heat Streams:

lb/hr	Temp.	Description
6.5×10^6	100 -- 120°F	Cooling Water
148×10^3	450°F	Flue Gas

Fuels:

Primary Fuel	Oil/Gas	110	MM BTU/hr
Secondary Fuel			MM BTU/hr
By-Product Fuel			MM BTU/hr

6.9 Isopropanol by the Direct Hydration of Propylene

This process and product belong to Industry #2869 Industrial Organic Chemicals. The total investment in facilities for the production of isopropanol is $160 million. This represents slightly more than .5% of the total investment in the industrial organic chemicals industry.

6.9.1 Process Description

Feedstock for this plant is propylene and water. These materials are combined catalytically to produce the isopropanol. Output from the plant is 500 tons per day of isopropanol and associated with this will be approximately 10 tons per day of fuel materials.

The unit operations in this process are gas compression, catalytic reaction, distillation and pumping. Distillation is the major energy use followed by the preheating of the reactor feed. This is a relatively simple process and does not require the equipment sophistication found in many of the other industrial organic chemical processes.

Isopropanol manufacture in the plant described here is similar to that of many other industrial organic chemicals in that large, single-train, continuously operating plants are the industry standard. Such plants are designed for long periods of operation without shutdown or startup. Again, it is critical that the utilities of this plant not be subject to interruption.

This plant operates at temperatures below 500°F and consequently should have potential, if redesigned, to use various advanced energy conversion technologies and associated topping systems for the cogeneration of electricity. The electricity consumption in the plant is relatively small and it is likely that cogenerated electricity would have to be exported.

The average energy consumption in this plant is 14 million BTU per ton of isopropanol produced. This represents 15% of the total operating cost.

6.9.2 Production Characteristics

Production capacity in the United States for isopropanol is 1.2 million tons per year. At the present time this production almost entirely uses a process based on sulfuric acid. However, it is anticipated that in future years the availability of a more pure stream of propylene for feedstock will shift the economics to favor the direct hydration process. The direct hydration process is in use in other countries and should have economic advantage in the U.S. in the future. It is expected that in the period from 1985 to 2000 all new plants will use the direct hydration process. Since this is a relatively new process, it is not anticipated that significant changes will be made from the plant design used in this analysis. As energy prices increase in relation to the rest of the economy, it is likely that there would be additional energy conservation in the form of additional heat exchanger surface or

waste heat boilers installed in this plant. This would not, however, substantially change the energy requirement for the plant operation.

For many years, isopropanol has been a feedstock in the production of acetone. Approximately one-half of the isopropanol production has gone to this use in the past. In recent years, because of the production of acetone as a by-product in the manufacture of phenol from cumene, the demand for isopropanol in the manufacture of acetone has slowed. However, this affect appears to have diminished and in the last two or three years demand for isopropanol and production capacity have both increased substantially. Isopropanol is used for solvent and medicinal purposes in many products throughout the economy. It is expected that the future growth of this product will be slightly faster than the growth of the economy and production will be increased two and one-half times by the year 2000.

Energy requirements in the United States for the production of isopropanol average about 3 trillion BTU per year. This is expected to increase to 6 trillion BTU in 1985 and to 11 trillion BTU by the year 2000.

There are five plants in the United States producing isopropanol today. The average production per plant is 685 tons per day. The plants range in size from 80 tons per day up to 1300 tons per day. Increments of expansion and new plants have been larger than 500 tons per day. It is

expected that the typical plant built after 1985 will have 1000 tons per day nominal production of isopropanol.

6.9.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Fuel (Oil or Gas)	Process Heater	Cooling Water
Steam (150 psig)	Distilling Columns	Flue Gas
Electricity	Gas Compressor	
"	Pumps & Lighting	

Electricity Requirements: Average 3600 KW; Peak +5% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
350,000	150		

Other Heat to Process: 160 MM Btu/hr of fuel (oil or gas) to a process heater to preheat the reactor feed streams.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
2000	Gas compressor	Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
17×10^6	100 -- 120°F	Cooling Water
600×10^3	400°F	Flue Gas

Fuels:

Primary Fuel	Oil/Gas	165	MM BTU/hr
Secondary Fuel			MM BTU/hr
By-Product Fuel	Gas	35	MM BTU/hr

6.10 Methanol Synthesis from the Partial Oxidation of Hydrocarbon Oils

This product and process belongs to the Industrial Organic Chemicals Industry SIC #2869. Investment in methanol plants in the United States is approximately $500 million dollars and represents about 2% of the total investment in the industrial organic chemical industry.

6.10.1 General Process Description

This plant uses oil or naphtha plus oxygen and steam for feedstock material. It produces 1500 tons per day of methanol. There is no direct fuel input to this process as the heat derived from the partial oxidation of the hydrocarbon feed material is used for the process heat. There are two reaction steps: the partial oxidation and the synthesis reaction, both of which are exothermic and supply heat to the process. This heat is recovered by using waste heat boilers and the steam therefrom is utilized in the distillation columns within the process. The steam is also used to drive the gas compressor which compresses the feed gas to the synthesis reactor.

In common with many other organic chemical production processes, this plant is a large, single-train operation, and is designed to operate for long periods of time (weeks or months) continuously without shutting down. Consequently, reliability of utilities and particularly the power supply is an important consideration.

The partial oxidation reactor in this process operates at a very high temperature (above 2000°F) and is normally associated with a waste heat boiler to recover heat in the form of steam. It is feasible that this reactor could be associated with advanced energy conversion technologies to convert some of the heat released into electricity at the elevated temperatures involved. This would, of course, require substantial redesign of the reactor and would have to be followed by extensive testing and demonstration to bring about commercialization. Waste heat in the form of steam is also recovered from the synthesis reactor, however, because of the lower temperature involved, (less than 600°F) the potential for cogeneration applications appears to be limited. It is feasible that various advanced energy conversion technologies could be incorporated into the design of this plant to enhance the cogeneration potential. Extensive testing and demonstration would be necessary before commercial acceptability would be had.

This process is different from many others in that no external energy input is required to accomplish the conversion of the feed materials to the methanol product. Sufficient heat is generated in the partial oxidation process to produce both the steam required in the feed mixture as well as the steam required for heat in the distillation operation.

6.10.2 Production Characteristics

Production facilities exist in the U.S. to manufacture 4.5 million tons per year of methanol.

None of this production capacity uses the partial oxidation process, although one such plant is under construction. The partial oxidation process has been commercialized and is being used outside the United States. The advantage of the partial oxidation process is that the primary feedstock is or can be a heavy oil or even a coal material. Such feedstocks are expected to be more readily available in the future and will eventually replace the use of natural gas as feed for this process.

If this plant is integrated within a chemical complex where the surplus steam production could be utilized, it is feasible that considerable more heat recovery could be installed, producing steam beyond the needs of the methanol plant. Since this plant represents a very advanced design, it is unlikely that there will be substantial changes over the next several years to meet either changing feedstock availabilities or fuel availabilities. The process does dissipate a lot of heat to the cooling water and changes will likely be made in the future to recover some of this energy.

The major use of methanol, which accounts for about 45% of all production, is in the production of formaldehyde. The remainder of the methanol is used in a wide variety of intermediate and end products. It is used as a feedstock in the manufacture of various organic chemicals, and it is widely used as a solvent. None of the major uses of methanol appear to be declining, and there is even some indication that methanol will

be used as a fuel for vehicles and possibly a fuel for electrical power generation in the future. In any event, it appears that methanol will grow in use substantially faster than the growth of the general economy, and its use is expected to triple by the year 2000, reaching a consumption of approximately 13 million tons per year.

There are 12 plants in the United States presently producing synthetic methanol. They range in size from less than 200 tons per day up to 2200 tons per day. The average plant size is 1100 tons per day. At least one new plant has been built in the 2000 tons per day size, however, the economies of scale at this size compared to operational difficulties is questionable. It is expected that future plants in the 1985 onward period will be at a level of 1500 tons per day output.

610.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Feedstock (Oil)	Oxidation Reactor	Cooling Water
H.P. Steam (1250 psig)	Gas Compressor	M.P. Steam (150 psig)
M.P. Steam (150 psig)	Distilling Columns	
Electricity	Pumps & Lighting	

Electricity Requirements: Average 1500 KW; Peak +5% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
110,000	1250	100%	21% @ 360°F (150 psig steam 79% @ 120°F (condensate)
23,000	150	0	---

Other Heat to Process: Much of the heat for this process is derived from the partial oxidation of the feedstock in the first reaction step.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
10,000	Gas compression	Steam

Waste Heat Streams:

lb/hr	Temp.	Description
9.4×10^6	100 -- 120°F	Cooling Water

Fuels:

Primary Fuel* _______ / 300+ _______ MM BTU/hr

Secondary Fuel _______ / _______ MM BTU/hr

By-Product Fuel _______ / _______ MM BTU/hr

*Process heat is obtained from the partial oxidation of the feedstock.

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6.11 Chlorine and Caustic Soda from Diaphragm Cells

These products and this process normally belong to the Alkalies and Chlorine Industry SIC #2812. Investment in the alkalies and chlorine industry is estimated at 2.8 billion dollars. Investment in chlorine and caustic plants is estimated at 4.4 billion dollars. The reason for this discrepancy is that many chlorine and caustic plants are associated with chemical complexes which are reported to the Department of Commerce and to the Census of Manufacturers as part of chemical industries other than the alkalies and chlorine industry.

6.11.1 General Process Description

The input materials for this process are salt and water. This is an electrolytic process and two products are made. Chlorine is produced in the amount of 1000 tons per day, and caustic soda (NaOH) in the amount of 1130 tons per day. There is also a small amount of hydrogen (28 tons per day) produced. This process involves a number of operations. Raw salt is treated and converted to a brine solution. It is then introduced to the electrolytic cells where the chlorine, caustic soda and hydrogen are produced. The caustic soda solution is treated and processed in evaporators for concentration. There is also filtration associated with the processing of the caustic soda. The chlorine is purified. There is the hydrogen removal operation and, although it is not part of the plant discussed here, there may be liquefaction of the chlorine for further sale.

The major energy uses for this process are the electricity required for the electrolytic cells, and the steam used in evaporating water from the caustic soda solutions. There is heat generated by the electrolysis process and that heat is carried out of the cells by the products. The heat in the caustic soda solution is retained and is used to either preheat the feed to the cells, or provide sensible heat to aid in the evaporation of the caustic soda solutions. The heat carried out by the chlorine in the gaseous form in this version of the process is not used and is removed by using cooling water. Energy conservation is achieved in the concentration of the caustic solutions by using multiple effect evaporators and by using the hot condensate from this operation in the salt treating operations.

In contrast to the plants and processes described previously in this report, the chlorine-caustic diaphragm cell process is not seriously disturbed by starting up and shutting down. The chlorine cells are arranged in sets and at any given time in the operation sets of cells will be off line and can be added into the production train when desired or others removed for servicing. Since the major reactants and products in this plant are not hydrocarbons as we have talked about previously, there is less hazard from a shutdown or a malfunction of the plant. Because chlorine-caustic plants are such large users of energy, and because they can be shut down or at least slowed down with reasonable ease, it has sometimes been advantageous to use these plants to

balance the load on the chemical complex main power plant when there are difficulties in other parts of the complex.

Within the chlorine-caustic plant relatively low temperatures are used, the maximum temperature being less than 320°F, and consequently the potential for generating heat or electricity in a cogeneration mode is limited if we use the plant itself as a source. However, the production of the steam and electrical power required as input to the chlorine-caustic plant could be accomplished by many energy conversion technologies and obviously these methods could include various cogeneration schemes. Since such mode of cogeneration would be external to the chlorine-caustic plant, no process modifications would be required.

The average total energy consumption of this plant is 17 million BTU per ton of chlorine produced. The cost of steam and power represents 44% of the total operating cost.

6.11.2 Production Characteristics

The production capacity for chlorine in the United States is 12.5 million tons per year. This capacity is split primarily between the mercury cell process (20%) and the diaphragm cell process (80%). It is expected, however, that mercury cell plants will no longer be constructed because of public reaction to mercury pollution in the effluent water. There are no significant environmental problems associated with the diaphragm cell process.

Since salt is available in essentially unlimited supply and is the only significant raw material for this process, it is not anticipated that raw material availabilities will have any effect upon this plant in future years.

There is opportunity in this plant for improved heat recovery and it is feasible that this will be done as the cost of energy increases in the future. There are also improvements that can likely be made through technical innovation to reduce the electricity consumption. However, modern diaphragm cell plants operate sufficiently close to the theoretical minimum electricity requirement that there is little room for improvement. Consequently, it is expected that for the foreseeable future there will be little change in diaphragm cell plants for chlorine manufacture and in the energy requirements for such plants.

Chlorine and caustic are large-volume basic chemical commodities that have long been available in the U.S. economy. It is not expected that there will be significant changes in the growth rate of their use over the next several years. The growth for these products is expected to be slightly less than the growth of the general economy and to increase to roughly 22 million tons per year by the year 2000.

The total energy consumption for the manufacture of chlorine and caustic soda is 180 trillion BTU per year. This is expected to increase to 240 trillion BTU per year in 1985 and to 300 trillion BTU per year in the year 2000.

There are at least 65 chlorine-caustic plants in the United States. Some of these plants are quite old and are small in size. The average size overall is 180 tons of chlorine per day. Newer plants, the so-called "world scale" plants, are approximately 1000 tons per day. This is the size of plant that will be built in the 1985 to 2000 time period.

611.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
L.P. Steam (20 psig)	Process Water (Heating)	Cooling Water
M.P. Steam (100 psig)	Evaporators	Waste Water
Electricity	Electrolysis Cells	
"	Pumps & Lighting	

Electricity Requirements: Average 120,000 KW; Peak +10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
175,000	100	Condensate	Used for Process Wa-.
90,000	20	0	" " " "

Other Heat to Process: Some heat is generated by the electrolysis of the salt solution. This heat is exchanged between the cell effluent and the fresh feed.

Hours of Operation at Average Conditions: 8500 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver

Waste Heat Streams:

lb/hr	Temp.	Description
5.4×10^6	100 -- 120°F	Cooling Water

Fuels:

Primary Fuel* ____ / ____ MM BTU/hr

Secondary Fuel ____ / ____ MM BTU/hr

By-Product Fuel ____ / ____ MM BTU/hr

*Steam and electricity are the only energy inputs.

6.12 Cryogenic Oxygen

This product and process belong to the Industrial Gases Industry SIC #2813. Capital investment in the industrial gases industry is approximately 2.2 billion dollars. Capital investment in oxygen facilities is approximately $800 million representing slightly more than one-third of the total investment in the industry.

6.12.1 General Process Description

This plant produces 2000 tons per day of oxygen at a pressure of 500 pounds per square inch from approximately 10,000 tons per day of air as the only feedstock material. Although this process employs some very sophisticated equipment, it is quite simple in concept and can be installed to be very reliable and to operate almost independently of day-to-day attention. The principal operations in this process are gas compression, heat exchange and distillation. The process involves a series of compressions and expansion of gas to achieve cooling in a cascade arrangement such that each stage of expansion will cool the products to an increasingly lower temperature until liquefaction occurs and the products can then be distilled separating the main constituents, oxygen and nitrogen.

Electricity is the only energy input to this plant and it is used primarily for gas compression.

Oxygen plants are frequently designed for unattended operation and consequently can be subject to shutdown in case of power failures.

The materials handled are not inherently dangerous provided the oxygen has a controlled release to the atmosphere.

Since this process operates below ambient temperatures, it is unlikely that energy conversion technologies suitable for cogeneration would find application within the process. However, the process does use large quantities of electricity and in combination with other major fuel-using or steam-using chemical processes the oxygen plant would be a logical user of cogenerated electricity.

This process consumes more than 400 kilowatt hours of energy per ton of oxygen produced. At this level, the cost of energy represents 45% of the total operating cost of the oxygen.

6.12.2 Production Characteristics

The approximate national production capacity for oxygen in the U.S. is 16 million tons per year. Essentially all of this production is by the cryogenic process.

The cryogenic process for oxygen production uses air as a raw material and consequently it is unlikely that there will need to be a change in the process in future years because of feedstock unavailability. Because energy represents such a significant portion of the production cost of this material, oxygen plants have been designed to have maximum efficiency in their energy utilization. Consequently, it is not expected that

the design of these plants will substantially change in future years because of increasing energy costs.

Oxygen is widely used throughout the U.S. economy. Oxygen is used in large quantities in many chemical processes. It is used in large volume by the steel industry, and it is also sold in large volume for welding use. There is expectation that the development of a synthetic fuels industry will constitute a large market for oxygen in the future. The use of oxygen has been growing more rapidly than the general economy and use is expected to quadruple by the year 2000.

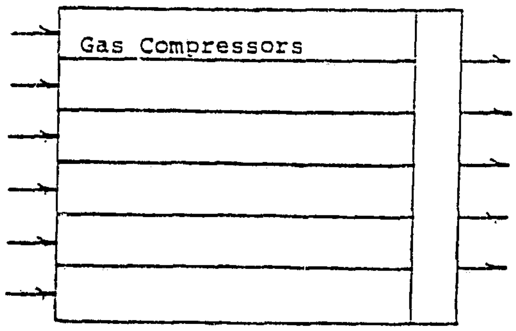
If we convert the electrical usage to British Thermal Units for comparison with other processes, the production of oxygen consumes 22 trillion BTU per year. This will increase to 33 trillion BTU by the year 1985 and to 66 trillion BTU in the year 2000.

There are more than 200 oxygen plants in the United States. They range in size from 10 tons per day up to 6000 tons per day. However, equipment to build a single-train oxygen plant larger than 2000 tons per day is unavailable and this represents the largest size for a single module. The average size of oxygen plant is 780 tons per day. It is expected that future oxygen plants will be built at the largest size that is commercially available, 2000 tons per day.

612.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Electricity	Gas Compressors	Cooling Water



Electricity Requirements: Average 34,000 KW; Peak +5% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
None			

Other Heat to Process: None.

Hours of Operation at Average Conditions: 8600 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
35,000	Gas Compression	Electricity*
12,000	Gas Compression	Electricity*

Waste Heat Streams:

lb/hr	Temp.	Description
700,000	100 -- 120°F	Cooling Water

els:

Primary Fuel* ____ / ____ MM BTU/hr

Secondary Fuel ____ / ____ MM BTU/hr

By-Product Fuel ____ / ____ MM BTU/hr

*A steam turbine or a combustion turbine could be used to drive

6.13 Low Density Polyethylene Resin

This product and process belong to the Plastics and Resins Industry SIC #2821. Investment in the plastics and resins industry is approximately 8.7 billion dollars. Capital investment in facilities for the production low density polyethylene is approximately 1.5 billion dollars, which is 17% of the total investment in the industry.

6.13.1 General Process Description

This plant produces 1000 tons per day of low density polyethylene resin by the high pressure polymerization of ethylene. Ethylene is the only feedstock to this process. In addition to the product resin, approximately 30 tons per day of by-product fuel material is produced. The principal operations in this plant are gas compression, the catalytic reactor, the product separation from unreacted feedstock, the extrusion of the product into pellets, and the materials handling. The major energy use to this process is the electricity to drive the motors on the gas compressors. The only other significant energy use is the steam required to maintain reaction temperatures in the reactors.

This plant is a continuous single-train operation and is not designed for frequent or irregular startups and shutdowns. Consequently, it is essential to the effective operation of this plant that the utility supply, including the power supply, have a high level of reliability.

The highest temperatures in this process are below 500°F and consequently the process units are unlikely to provide much opportunity for cogeneration within the plant. However, because of the electricty requirement and because of the steam requirement, it is feasible that a cogeneration unit could be employed to provide these two energy requirements to the process.

The average energy consumption of this plant is 5 million BTU per ton of polyethylene resin. This represents 6.5% of the total operating cost.

6.13.2 Production Characteristics

The production capacity for low density polyethylene in the United States is 3 million tons per year. There are two principal processes by which this product is manufactured, the autoclave reactor process and the tubular reactor process. These processes are quite similar in all aspects other than the type of reactors employed and the energy consumption in each process is roughly equivalent.

This plant does not have any significant adverse materials in the effluent streams and it is unlikely that future pollution control requirements will cause an increase in the power consumption or require any substantial alteration of the process.

There is much energy lost in the cooling of the reactors and the gas being compressed in the compressors and it is likely that as newer

techniques are developed means will be found to recover a significant portion of this heat for useful purposes. The mechanism by which this will be accomplished and how this heat will be utilized are not clear at the present time.

Since this plant uses only electrical power and steam as energy inputs and both of these can be produced from a variety of fuels, it is not anticipated that fuel availability will have an effect upon either energy consumption or the plant design in the future. Similarly, the raw materials, primarily ethylene, can be produced from many different sources and raw material availability will not critically affect the design and operation of this plant in the future.

Low density polyethylene has the largest volume of use in the United States at the present time of any of the common plastic base materials. This demand has been growing at a high rate, averaging close to 10% per year in recent past periods. It is expected that a large demand growth will occur in the next several years, and that by the year 2000 there will be a fourfold increase in the use of low density polyethylene. Polyethylene film is used in a variety of ways; for packaging materials, for moisture sealing (in building construction), and for household food wrap. Polyethylene is also molded to make many products, such as bottles and bottlecaps and toys.

At the present time, the manufacture of low density polyethylene uses approximately 18 trillion

BTU per year. This energy use is expected to increase to 38 trillion BTU per year in 1985 and will grow to 60 trillion BTU in the year 2000.

There are 20 low density polyethylene plants in the United States today. These plants range in size from 100 tons per day up to 1000 tons per day and the average is very close to 500 tons per day. The newest single-train plants being built today are approximately 1000 tons per day in size and it is expected that this size will be the standard for many years to come.

613.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Steam	Feed Preheater	Cooling Water
Electricity	Gas Compressors	
"	Extruder Motor	
"	Pumps & Blowers	

Electricity Requirements: Average 55,000 KW; Peak +5-10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
16,000	400	Condensate	---

Other Heat to Process: None.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
33,000	Gas Compression	Electricity*
18,000	" "	
15,000	" "	

Waste Heat Streams:

lb/hr	Temp.	Description
6×10^6	100 -- 120°F	Cooling Water

Fuels:

Primary Fuel* None / MM BTU/hr

Secondary Fuel / MM BTU/hr

By-Product Fuel / MM BTU/hr

*Steam turbines could be used in place of the electric motors to drive the gas compressors.

6.14 Styrene Butadiene Rubber (SBR) by the Emulsion Process

This product and process belong to the Synthetic Rubber Industry SIC #2822. Investment in the synthetic rubber industry is 1.1 billion dollars. The investment in production facilities for SBR is over 700 million dollars and represents about 75% of the total investment in the industry.

6.14.1 General Process Description

In this process, styrene and butadiene are mixed together under carefully controlled temperature conditions and react to produce polymeric (latex) material which is then solidified and recovered in the form of styrene butadiene rubber. The plant produces 350 tons per day. The principal operations in this plant are pumping, mixing, distillation, screening, washing, drying and materials handling.

Electricity use is distributed throughout the plant in the various pumping, mixing, screening and drying operations. Steam consumption is concentrated largely in the distilling operation.

This plant will operate several lines of production in parallel having duplicate reactors and many other facilities duplicated. Consequently, it is feasible that parts of the production line can be shut down at random times without bringing the entire plant down. This process will be less adversely affected by power failures than many of the processes previously discussed.

Low temperatures are employed in this process. Essentially all steps are occurring at temperatures of 200°F or less. Consequently, energy conversion processes generating high temperatures are not required and the potential for cogeneration from this type of equipment does not exist. However, in the production of the steam and the electricity required for this process, cogeneration techniques would be feasible.

The average energy consumption for this process is 4.7 million BTU per ton. At this level, energy cost represents about 2.5% of total operating cost.

6.14.2 Production Characteristics

The production capacity for SBR in the United States is 1.5 million tons per year. More than 80% of this is produced by the emulsion process. Few changes are expected in this process over the next 20 or more years. The required temperature levels are very low and the potential for energy conservation is relatively small from waste heat recovery or additional heat prevention measures. Environmental protection requirements are small and future changes are not expected to significantly alter the energy use in this process.

This is the principal source of rubber for the U.S. economy. SB rubber is widely used in automobile and truck tires and in other commercial and industrial rubber products. Use is expected to grow at the general level of the economy and is expected to double by the year 2000.

This process consumes 7 trillion BTU per year in the United States and this energy consumption will increase to about 9 trillion BTU per year by 1985 and to 13 trillion BTU by the year 2000.

There are 13 SB rubber plants in the United States varying in size from 100 tons per day up to 1000 tons per day. Average plant size is about 350 tons per day. Plant size can be increased incrementally by adding reactor trains. It is expected that the typical new plant of the 1985 to 2000 time period will be 350 tons per day.

6.143 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
M.P. Steam (150 psig)	Dryer	Cooling Water
L.P. Steam (15 psig)	Distillation Column	Condensate
Electricity	Refrigeration Compressor	
"	Stirring Motors	
"	Pumps & Extruders	
"	Conveyor Motors	

Electricity Requirements: Average 7500 KW; Peak +5-10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
32,000	15	Condensate	---
1,300	150	Condensate	---

Other Heat to Process: None.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
3,000	Refrigeration Compressor	Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
2×10^6	100 -- 120°F	Cooling Water

Fuels:

Primary Fuel --- / MM BTU/hr

Secondary Fuel --- / MM BTU/hr

By-Product Fuel --- / MM BTU/hr

6.15 Polyester Fiber Production

This product and process belong to the Non-Cellulosic Synthetic Fibers Industry SIC #2824. Total investment in this industry is 9.1 billion dollars. The total investment in facilities for the production of polyester fiber is 3.7 billion dollars representing slightly more than 40% of the total investment in the industry.

6.15.1 General Process Description

Feedstock for this plant is ethylene glycol and dimethyl terephthalate. These materials react together to form hydroxyethyl terephthalate ester. The ester is then polymerized to form the polyester product. The plant produces 250 tons per day of polyester fiber materials. There is a methanol by-product in the amount of 80 tons per day.

Major operations in this plant include melting vessels, screw conveyors for handling solid materials, esterification reactors, pumps, polymerization reactors, distilling columns, and the extruding, spinning and drawing equipment for the fiber threads.

Electricity represents 55% of the energy input to this process. Most of this electricity is used in operating the equipment involved in spinning the fiber. A large portion of the electricity is used in the air conditioning required to dissipate the heat from the fiber as it cools from its molten state to the solid fiber. The other significant energy uses in this process are the steam

to the melting vessels and also steam to the distilling columns. The third most significant energy use is the heat to the polymerization reactors which is usually provided by circulating DOWTHERM. The energy input to this process is removed in two ways. Much of the energy is removed as low temperature cooling water and the remainder comes out as low temperature heat in the air cooling provided by the air conditioning system.

This plant is a multiple-train operation, will have several reactors in parallel and all of the major items of process equipment will be duplicated. Consequently, portions of the plant can be shut down and started up independent of the rest of the plant. Because these production trains are designed for regular startup and shutdown, a power failure or a loss of other utility services is not critical in the same sense as for many of the other processes described earlier in this report.

This process uses temperatures in excess of 500°F and most of this heat is presently dissipated through cooling water. It is anticipated that future designs might incorporate additional waste heat recovery in the form of steam or alternatively other energy conversion processes could be used which would be appropriate for cogeneration of electricity as well as steam. Cogeneration technologies would also have application in the production of the electricity, the steam and the DOWTHERM heating required for this process.

This plant requires slightly more than 10.5 million BTU per ton energy input. This level of energy input represents 5% of the total operating cost.

6.15.2 Production Characteristics

The production capacity in the United States for polyester fiber is 1.5 million tons per year. Although individual manufacturers are reluctant to describe their process, it is believed that almost all polyester fiber is produced by comparable basic processing and the individual plants differ only in relatively minor features. Energy consumption in these plants is largely determined by the type of fiber produced and for comparable fiber outputs energy use should be similar from one plant to another.

These plants do not require unique fuel materials or energy inputs and the feedstock raw materials can be synthesized from a number of sources such as petroleum or even coal. Consequently, it is expected that the basic design of this plant will stay as developed here for many years into the future and the energy consumption per unit of output should not change substantially. There will be, in all likelihood, additional heat recovery improvements made which could supply low pressure steam to other processes or provide electricity which could be used within the polyester plant. It is expected, though, that these developments will be of an incremental nature and not have a significant effect on the overall energy consumption.

The use of polyester fiber has grown rapidly in recent years. This product has replaced naturally occurring fibers, such as cotton, in many textile and fabric uses throughout the economy. It is expected that polyester use will continue to grow. However, since the displacement market is essentially saturated, the growth will slow substantially. However, the future growth rate will still be larger than the growth of the economy and the use of polyester fiber should triple by the year 2000.

The production of polyester fiber consumes approximately 30 trillion BTU per year. This will increase to 55 trillion BTU per year in 1985 and further increase to 75 trillion BTU per year by the year 2000.

There are 34 polyester fiber plants in the United States. These plants range in size from 3 to 300 tons per day capacity. The average plant size is 200 tons per day. The capacity growth for the next few years will be mainly incremental additions to existing plants. By 1985 it is expected that typical new plant construction will be at the nominal size of 250 tons per day.

6.15.3 Energy Characteristics

Energy Schematic:

Inputs		Conversion Unit		Outputs
Steam	→	Distilling Columns	→	Cooling Water
Fuel (Oil or Gas)	→	Dowtherm® Heater	→	Cooling Air
Hot Dowtherm®	→	Reactor Vessels	→	Hot Dowtherm®
Hot Dowtherm®	→	Distilling Columns	→	
Electricity	→	Fiber Spinning Motors	→	
"	→	Air Conditioner		

Electricity Requirements: Average 32,000 KW; Peak +10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
30,000	250		

Other Heat to Process: 57 MM Btu/hr of primary fuel (oil or gas) is used to heat circulating Dowtherm®.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver

Waste Heat Streams:

lb/hr	Temp.	Description
10×10^6	100°--120°F	Cooling Water
750×10^3	90°--110°F	Air for Cooling Fibers

Fuels:

Primary Fuel Oil/Gas / 57 MM BTU/hr

Secondary Fuel --- / MM BTU/hr

By-Product Fuel --- / MM BTU/hr

6.16 Nylon 66 Fiber Production

This product and process belong to the Non-Cellulosic Synthetic Fibers Industry SIC #2824. Total investment in this industry is 9.1 billion dollars. The capital investment in production facilities for nylon fiber is 2.6 million dollars representing almost 30% of the investment in the industry.

6.16.1 General Process Description

The feedstock for this plant is hexamethylene diamine (HMDA) and adipic acid. These two materials are reacted together to produce a compound called nylon salt. The nylon salt is purified and then polymerized to form the nylon compound. The nylon material is solidified, dried and becomes what is called a nylon chip. The nylon chip is then melted, extruded, spun and drawn into the nylon fiber. This plant will produce 150 tons per day of fiber of various qualities.

The major processing operations in this plant are the mixing, batch reactors, drying, solidification, melting, extrusion, and fiber spinning and drawing.

The major energy input to this process is the electrical power to the fiber operation. Electricity is used for the motors in the extrusion and the spinning-winding operations and a large amount of electricity is used in the air conditioning for the air cooling required in this phase of the operations. Another major energy use is the steam required in the evaporation and

concentration of the nylon salt. Also, DOWTHERM heat is provided to the polycondensation (polymerization) reactor. Other less significant energy uses are for pumping and materials handling.

This plant uses parallel production trains, each of which can be operated relatively independently and can be shut down and started up on a regular basis. Consequently, power failures would have less significance to this plant than in many other types of chemical production described in earlier sections of this report.

The melting point of Nylon 66 is above 500°F and consequently temperatures at this level are required at several points in the production process. It is feasible that for generating these temperatures technology could be employed that would be able to use cogeneration or to produce electricity simultaneously. The production of the electricity, steam and the DOWTHERM heat required in the operation of this plant could all employ cogeneration and have a simultaneous production of electricity and useful heat.

The average energy consumption in this plant is 14 million BTU per ton of Nylon 66 fiber. This process is not energy intensive in terms of cost and the energy input represents less than 2% of the total operating cost.

6.16.2 Production Characteristics

The approximate production capacity for all nylon, Nylon 6 as well as Nylon 66, is 1 million tons per year. 70% of this production is Nylon 66.

The raw materials for this process can be synthesized from a number of starting materials and it is not expected that availability of raw material will affect the process or require changes to the process in the future. Fuel for this process can be any of several fossil or synthetic fuels and, again, this will not affect the energy consumption within the process. It is expected that as energy prices increase, additional heat recovery will be installed on the process and there will be some reduction in the energy intensity because of this.

Nylon is widely used in textiles and in industrial plastics where tensile strength or abrasion resistance is needed. The market has been growing faster than the general economy and use is expected to at least double by the year 2000.

On a national basis, the energy required for the production of nylon is approximately 14 trillion BTU per year. This will increase to 20 trillion BTU in 1985 and to 25 trillion BTU by the year 2000.

There are 30 plants in the U.S. producing nylon. They range in size from 15 to 300 tons per day. The average size is 150 tons per day. Because of

the modular nature of this process, capacity increases will be probably in increments of 150 tons per day or less.

616.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Steam	Evaporator	Cooling Water
Steam	Distilling Column	Cooling Air
Fuel (Oil or Gas)	Dowtherm® Heater	Hot Dowtherm
Hot Dowtherm	Fiber Spinning Packs	
Hot Dowtherm	Polymerization Reactor	
Electricity	Air Conditioning, Fiber Spinning & Drawing, Pumps	

Electricity Requirements: Average 11,000 KW; Peak +10% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
23,000	30	Condensate	---

Other Heat to Process: 25 MM Btu/hr of primary fuel (oil or gas) is used to heat circulating Dowtherm®.

Hours of Operation at Average Conditions: 8760 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver

Waste Heat Streams:

lb/hr	Temp.	Description
2.5×10^6	100°--120°F	Cooling Water

Fuels:

Primary Fuel Oil/Gas / 25 MM BTU/hr

Secondary Fuel --- / MM BTU/hr

By-Product Fuel --- / MM BTU/hr

6.17 Ammonia Synthesis

This product and process belong to the Nitrogenous Fertilizer Industry SIC #2873. The total capital investment in nitrogenous fertilizers is 3.9 billion dollars. The capital investment in production facilities for ammonia is approximately 2.5 billion dollars. This represents slightly more than 60% of the total investment in the industry.

6.17.1 General Process Description

The input materials for this process are air, steam, and various alternative hydrocarbon materials ranging from natural gas to coal. It is only necessary that the reformer furnace at the beginning of the process be designed to accomodate the particular hydrocarbon feedstock employed. Products from the reforming furnace are carbon dioxide, carbon monoxide, nitrogen and hydrogen. This stream is processed in a shift conversion reactor to produce the proper ratio of nitrogen and hydrogen. The carbon dioxides are scrubbed out and the nitrogen-hydrogen stream is compressed and sent to the synthesis reactor where ammonia is formed. The plant produces 1200 tons per day of ammonia and, in this case, uses a starting feedstock of natural gas.

This plant is designed so that the entire energy input is in the fuel to the reforming furnace. The reforming furnace is designed to produce steam as a by-product (waste heat recovery) and this steam is used primarily for operating the gas compressors preceding the ammonia reaction.

The major energy using operations in this plant are the reformer furnaces, the compressors, and the carbon dioxide stripping column.

This plant is a large single-train production operation. It is designed to operate continuously 24 hours per day, 7 days per week. It is not feasible to start up and shut down this plant at frequent intervals. Consequently, reliability of the power supply, as well as other utilities, is a critical consideration.

This plant uses high temperatures (1500°F) and consequently is a good candidate for alternative energy conversion technologies which may have potential for cogeneration. However, the plant as specified here has a high thermal efficiency and much of this heat is recovered in the form of steam and then subsequently used within the process. Although the electrical power input to this process is small (3500 kilowatts) in relationship to the fuel requirement for the reforming furnace, it is of course feasible that this electrical power could be produced from a cogeneration technology either within or outside of the ammonia plant.

The energy input to this plant is almost entirely in the fuel to the reforming furnace and amounts to an average 12.5 million BTU per ton of ammonia produced. At this level of fuel input, the cost of energy represents 21% of the total operating cost.

6.17.2 Production Characteristics

The annual production capacity for ammonia in the United States is approximately 18 million tons per year. The principal difference between ammonia plants are the size, hydrocarbon feedstock and the amount of heat recovery. As natural gas becomes less available future plants will employ more liquid hydrocarbons for feed and they will also incorporate more heat recovery in their design. It is not expected that ammonia plants will get much larger than the largest plants being designed and installed today as the economies of scale at this level are becoming questionable. The plant that we have used for example here represents our best estimate of the magnitude of heat recovery and size and feedstock that will be considered typical in the 1985 to 2000 time period.

Ammonia is the second or third largest volume chemical product in the United States. It has had a rapid growth rate in earlier periods, however, it has slowed in recent years and is not expected to grow substantially faster than the economy for the foreseeable future. Ammonia is used largely in agriculture and the growth of its use will depend primarily upon the demand for agricultural products together with the productivity requirements from the cropland. It is expected that the use of ammonia will be slightly less than double the current use and will be at a level of 34 million tons per year by the year 2000.

There are more than 90 ammonia plants in the United States today. They range in size from 50 to 2000 tons per day and average about 220 tons per day. The newer plants are in the range of 500 to 1200 tons per day. New plant construction in the 1985 to 2000 time period is expected to average about 1200 tons per day in size.

617.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Fuel (Oil/Gas)	Reformer Furnace	H.P. (1500 psig)
H.P. Steam (1500 psig)	Gas Compressors	Flue Gas
M.P. Steam (600 psig)	Diluent for Feedstock	Cooling Water
M.P. Steam (600 psig)	Pumps & Blowers	M.P. Steam (600 psig)
L.P. Steam (50 psig)	Distilling Columns	L.P. Steam (50 psig)
Electricity	Pumps & Lighting	

Electricity Requirements: Average 3500 KW; Peak +5% KW

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
560,000	1500	100%	280°-490°F

Other Heat to Process: 500 MM Btu/hr of primary fuel (oil or gas) to the reformer furnace.

Hours of Operation at Average Conditions: 8400 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
12,700	Gas Compression	Steam
25,000	" "	"
8,500	Refrigeration	"

Waste Heat Streams:

lb/hr	Temp.	Description
24×10^6	100°-120°F	Cooling Water
500×10^3	400°F	Flue Gas
560,000	(1500 psig)	Superheated Steam

Fuels:

Primary Fuel	Oil/Gas	/ 500	MM BTU/hr
Secondary Fuel	---	/	MM BTU/hr
By-Product Fuel	---	/	MM BTU/hr

6.18 Phosphoric Acid by the Wet Process

This product and process belong to the Phosphatic Fertilizers Industry SIC #2874. Investment in this industry totals 2.5 billion dollars. The investment in phosphoric acid is approximately .8 billion dollars or about one-third of the total investment in the phosphatic fertilizers industry.

6.18.1 General Process Description

This plant produces two grades of phosphoric acid; 500 tons per day of orthophosphoric which is equivalent to approximately 54% phosphorus pentoxide (P_2O_5), and 500 tons per day of super phosphoric acid, which represents 70% P_2O_5. Input materials for the process are concentrated phosphate rock, sulfuric acid and water. The basic process involves dissolving the phosphate rock in sulfuric acid, controlling the acidity and temperature to precipitate calcium sulfate, filtering out the solid sulfate material and leaving the phosphoric acid that is formed in solution. This is followed by evaporation to concentrate the phosphoric acid solution to the desired acid strength in the product. Major operations in the process are mixing, vent gas scrubbing, filtrations, vacuum evaporation, hot gas evaporation and pumping. The major energy inputs to this process are the steam to the vacuum evaporation and steam to the wash water heating and fuel to the submerged gas evaporator. The electrical requirements are much smaller in total energy equivalent than the steam and fuel requirements, and are distributed throughout the plant for pumping gas compression power.

This plant is a large single-train continuous operation. It runs 24 hours per day, 7 days per week with an on-stream factor of .9. The plant is not designed to be started up or shut down at frequent intervals. Normal runs will be for many weeks at a time. Consequently, interruption in the supply of power or other utilities constitutes a serious problem. However, power failures in this plant would be less critical than in many of the organic chemical processes discussed earlier.

The portion of this process where the acid is concentrated to the super phosphoric acid uses temperatures above 500°F. It is possible that the submerged gas evaporator could be replaced by different technology and could employ cogeneration to produce electricity at this point. Other portions of this plant generally operate at significantly lower temperatures where steam is adequate for the heating requirements and cogeneration technologies probably are not feasible. However, in the production of the steam, cogeneration schemes are likely to be viable.

The average energy consumption in this plant is 4.4 million BTU per ton. At this level the cost of energy represents 7.5% of the total operating cost.

6.18.2 Production Characteristics

The approximate production capacity in the United States for phosphoric acid is 10 million tons (P_2O_5) per year. Approximately 10% of this

capacity is produced by electric furnace and represents a very pure grade of phosphoric acid which is too expensive to be used in fertilizers and has been used in the past primarily for detergents. Production capacity for wet process phosphoric acid is approximately 9 million tons (P_2O_5) per year.

This plant has some significant environmental pollution hazards. Fluorine is generated as a by-product and fluorine gas is in the vent gases coming from the reaction step and also from the concentration steps. It is necessary these effluents be thoroughly scrubbed for fluorine removal. More stringent air pollution requirements could necessitate additional processing steps and require additional energy input to this process.

The major feedstock for this plant, phosphate rock, will be in shorter supply as time progresses and it will be necessary to start with primary rock having lower phosphate content. However, the rock is normally beneficiated to a standard phosphate level at the mine and the energy input required for this is not considered part of the phosphoric acid plant requirement.

This process for the production of phosphoric acid is the largest single use of sulfuric acid in the United States. It is contemplated that sulfuric acid will be in long supply for many years to come because of the emphasis on recovering sulfur oxides in the burning of coal and

sulfur-containing fuel oils. As a result, it is not expected that the phosphoric acid process will be affected by any shortage of sulfuric acid.

The phosphoric acid product from this process is used almost entirely in fertilizers and its growth is associated with crop production. Growth in the use of phosphoric acid increased faster than the economy in recent past periods as the yields of food crops per acre was increased. It is expected that in the future this demand will grow approximately at the same rate as the economy and will double by the year 2000.

The wet process for sulfuric acid on a national basis consumes approximately 35 trillion BTU per year. This is expected to increase to 48 trillion in the year 1985 and will be 60 trillion BTU by the year 2000.

There are more than 35 plants in the United States producing phosphoric acid by the wet process. They range in size from 50 tons per day up to 2000 tons per day. The average size is about 780 tons per day. New plant construction is in the neighborhood of 1000 tons per day and it is expected that future construction, 1985 and later, will be at this same level.

6 18.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Fuel (Oil or Gas)	Gas Evaporator	Cooling Water
M.P. Steam	Vacuum Ejectors	
M.P. Steam	Wash Liquor Heater	
L.P. Steam	Vacuum Evaporator	
Electricity	Air Compressor	
"	Pumps, Mixers & Lighting	

Electricity Requirements: Average 4000 KW; Peak +10% /KW/

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
65,000	25		
27,000	125		

Other Heat to Process: 65 MM Btu/hr of fuel (oil or gas) to the submerged gas evaporator. Also, heat is generated by the reaction between the phosphate rock and the sulfuric acid.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver
750	Air Compressor	Electricity

Waste Heat Streams:

lb/hr	Temp.	Description
7.3×10^6	100-120°F	Cooling Water

Fuels:

Primary Fuel	Oil or Gas	65	MM BTU/hr
Secondary Fuel	---		MM BTU/hr
By-Product Fuel	---		MM BTU/hr

6.19 Carbon Black by the Furnace Process

This product and process belong to the Carbon Black Industry SIC #2895. Total investment in the industry is approximately $600 million.

6.19.1 General Process Description

The input materials for this process are the primary fuel and the aromatic oil feedstock. The aromatic oil is injected into the combustion zone of a burner and the products of combustion are immediately quenched to produce carbon. 300 tons of the carbon (carbon black) are produced per day in this plant. The major operational units are the reactor, a cyclone separator, bag filter, dryer, pulverizers, and materials handling equipment.

The primary energy input to this process is the fuel to the reactors. A modest amount of steam and electricity are used elsewhere in the process, however they do not represent a significant energy use at any one point in the process. Waste heat is dissipated in the flue gas leaving the bag filter operation.

This plant will have several production trains operating in parallel and individual trains can start up and shut down independently. These trains in normal use may be started and stopped almost on a daily basis. Consequently, interruption of the power supply is not a critical problem in this plant.

It is feasible that the reactor used in this process which operates at high temperatures (above 2000°F) could be modified to incorporate energy conversion technologies adaptable to cogeneration. This would take a substantial development program since the reactors are designed for optimum quality of the carbon black produced and any energy recovery aspects would be strictly secondary.

The flue gas produced in existing processes and specifically in the plant described here, contains a significant amount of carbon monoxide. It would be feasible to install a conventional carbon monoxide boiler and (with some supplementary firing) produce steam from the fuel value contained in the flue gas. The steam production would be much in excess of the steam requirements of the plant and could be used to produce surplus electrical power for sale.

The average energy consumption for this plant is 9 million BTU per ton of carbon black produced. At this level of energy use the total direct energy input represents 21% of the operating cost of the carbon black. If we consider that the portion of the feedstock oil which is burned also contributes to the energy input, then energy input on this basis represents 43% of the operating cost.

6.19.2 Production Characteristics

The approximate total United States production capacity for carbon black is 2 million tons per

year. There are three processes that have been used for making carbon black. These are the furnace process, the channel process, and the thermal process. Both the channel process and the thermal process are used only to a small extent and the furnace process, which is the one described in this report, accounts for more than 90% of all carbon black production.

Feedstock availability for this process is not likely to be a problem in the future nor is it likely to necessitate any change in the process. A high carbon to hydrogen ratio in the feedstock is very desirable and it is expected that the heavier crude oils that will be available in the U.S. as time progresses and also the oils from coal liquefaction will constitute very attractive feedstocks for the carbon black process.

This plant has an extremely low solid particulate emission to the atmosphere because of the use of the bag filters to trap the carbon in the flue gas. If the carbon monoxide boilers mentioned previously are installed, it should be possible to have extremely clean atmospheric discharges from this plant. While the addition of the carbon monoxide boiler will increase the energy recovery, it will have relatively little impact on the total energy use of the plant since it will produce energy for export to other users. It is feasible that the combustion air for this process could be enriched with oxygen to reduce the nitrogen content of the flue gas, in this case the flue gas containing the carbon monoxide could be used as a synthesis gas for other processes.

More than 90% of all carbon black is used in rubber materials, most of it going into truck and automobile tire rubber. The carbon black imparts very desirable qualities to the rubber, improving its strength, abrasion resistance and other characteristics. The use of carbon black is expected to closely parallel the use of rubber and will grow at a rate somewhat slower than the growth rate of the general economy. By the year 2000 demand is expected to be about 75% higher than today for a total requirement of 3.5 million tons per year.

There are 30 furnace black plants in the United States. These plants vary in size from 100 tons per day up to 400 tons per day, the average size being about 190 tons per day. Most of the production increase occurs in the form of incremental addition of production trains to existing plants. It is expected that in the 1985 to 2000 time period these planned additions will be in increments of 300 tons per day.

619.3 Energy Characteristics

Energy Schematic:

Inputs	Conversion Unit	Outputs
Fuel (Oil or Gas)	Reactor	Flue Gas
Steam	Rotary Dryer	
Electricity	Pumps & Blowers	
"	Pulverizer/Pelletizer	
"	Conveyors	
"	Lighting	

Electricity Requirements: Average 4000 KW; Peak +15%

Steam Requirements (Process and Heating):

lb/hr	psig	Returns	Temp. of Returns
20,000	50	Condensate	---

Other Heat to Process: 112.5 MM Btu/hr of fuel (oil or gas) to the reactors.

Hours of Operation at Average Conditions: 7900 hr/yr

Large Horsepower Loads:

Normal hp	Service	Probable Driver

Waste Heat Streams:

lb/hr	Temp.	Description
520,000	400°F	Flue Gas from Reactors

Fuels:

Primary Fuel Oil or Gas / 112 MM BTU/hr

Secondary Fuel ______ / ______ MM BTU/hr

By-Product Fuel ______ / ______ MM BTU/hr

6.20 Central Steam Plants

6.20.1 General Considerations

Approximately 65% of all fuel used in chemical plants is employed to generate steam. Essentially all of this steam is produced in boilers that operate independent of the individual chemical processes serviced with the steam produced. These boilers will usually be grouped in a central steam plant within the chemical plant complex. Although, in some cases, a given complex may have two or more steam plants geographically separated by a short (probably less than one mile) distance, we will treat these cases as a single steam plant.

Each steam plant will consist of as few as two or up to twenty or more individual boilers depending on the size of the steam load. The rated capacity of the boilers will substantially exceed the average steam demand of the complex. For the overall industry, it appears that capacity exceeds average demand by about 80%.

The individual boilers in most chemical complexes will have a range of ages. The working life of a field erected boiler is 25-50 years. A shop fabricated ("package") boiler will have a shorter working life, 15-30 years. The boiler life is highly dependent upon the quality of the feed water used. Quite often, the spare capacity in a steam plant consists of older, less efficient boilers which are either operated considerably below maximum rating, or are held idle in case of need for emergencies.

The steam plant average steam demand in the chemical industry is distributed as shown in the table below.

Size of Average Steam Demand MM lbs/hr	Number of Steam Plants	Total Steam Load MM lbs/hr
Over 1.0	57	100
.25-.99	59	34
.05-.24	196	18
Below .05	1118	16

This tabulation represents only the plants in the major energy consuming subindustries of the chemical industry. However, it accounts for more than 90% of the total steam generation.

It can be seen that 60% of the steam use occurs in plants producing more than one million pounds per hour of steam. Twenty percent of the load is in the fifty thousand to one million pound per hour range and another twenty percent is below fifty thousand pounds per hour average load. These are the three size ranges that will be characterized by describing a "typical" steam plant for each.

Since we are interested in the steam plant of the 1985 to 2000 time period, it can be expected that the average steam demand for a given plant will increase between now and then. There will, however, be some offsetting factors which will tend to inhibit the rate of growth. Between now and 1985 will be a period of increased emphasis on heat recovery, and there will be many heat recovery boilers installed to absorb much of the

growth in the steam demand. Also, many of the new chemical plants put into production will be much more efficient in energy (steam) use than their predecessors being retired. For these reasons, we will assume that the average steam demand of 1985 will be comparable to that of today.

6.20.2 The Large Steam Plant

This plant will have an average steam load of 1,750,000 pounds per hour, with the following range of boilers.

Number of Boilers	Rated Capacity lbs/hr each	Total Capacity lbs/hr
1	650,000	650,000
2	350,000	700,000
6	250,000	1,500,000
9		2,850,000

Steam pressure levels in this plant will be 600 psig, 200 psig and 30 psig.

The three largest boilers will operate on oil or gas fuel and will be rated at 625 psig steam pressure. The six smaller boilers will be rated at 250 psig steam pressure.

The steam plant will also generate 25 megawatts of electricity from two turbines extracting at 200 and 30 psig with partial condensation.

This plant will grow in the 1985-2000 time period by the replacement of the six smaller boilers with two or more 650,000 lbs/hr boilers. These

new boilers will likely be fired with coal or coal derived fuels and be rated at 1250-1525 psig steam pressure. At this time, new steam turbines will be installed to take advantage of the higher steam pressure and generate additional electricity.

6.20.3 The Medium-Size Steam Plant

This plant will have an average steam load of 615,000 pounds per hour with the following boilers.

Number of Boilers	Rated Capacity lbs/hr. each	Total Capacity lbs/hr
3	250,000	750,000
3	125,000	375,000
6		1,125,000

All boilers will be primarily gas fired with optional oil firing.

Steam pressure levels in this plant will be 400 psig, 150 psig and 25 psig. The three largest boilers will be rated at 625 psig steam pressure and the three smaller boilers will be rated at 200 psig steam pressure.

This plant will have no electrical power generation.

This plant will grow in the 1985-2000 time period by the addition of higher pressure boilers and will add electrical generation from the high pressure steam. The new boilers would likely use fluidized bed coal combustion.

6.20.4 The Small Steam Plant

This plant will have an average steam load of 50,000 pounds per hour with the following boilers.

Number of Boilers	Rated Capacity lbs/hr. each	Total Capacity lbs/hr
4	25,000	100,000

All boilers will be gas fired and rated at 250 psig.

Steam pressure levels in this plant will be 200 psig and 25 psig.

The plant will have no electrical generation.

This plant will grow in the 1985-2000 time period by the addition of one or more 100,000 pounds per hour boilers operating on residual oil fuel.

CTAS Plant Data Sheet

A. Plant Name/Size: Ethylene from Gas Oil by Steam Cracking / 1500 tons/day

B. Products:

Product	lb/yr, etc.
Ethylene	1510 tons/day
Propylene	860 "
Butadiene	240 "
Fuels (incl. gasoline)(Net)	2500 "

C. Plant Kilowatt Requirements: Average 5700 kW; Peak ________ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
150,000	@	1500	0	
	@			
	@			

E. Other Heat to Process (Describe):

This plant also uses: 123,000 #/hr of 600 psig steam
581,000 #/hr of 150 " "
428,000 #/hr of 75 " "
128,000 #/hr of 35 " "

and 1.9×10^9 Btu/hr of by-product fuel--all of which are self produced in the process.

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
37,000	(gas compression 0-100 psig)			Steam
38,000	"	" 0-250 psig)		"
5,800	"	" 0-212 psig)		"

H. Operational Considerations:

This plant operates continuously around the clock, 7 days per week.

I. Waste Heat Streams:

lb/hr	Temp.	Description
44,000	260 F	35 psig steam
2.5×10^6	350 F	Flue gas
38×10^6	100-120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Ethylene / 1500 tons/day

J. Fuels: Primary Fuel ______ / ______ mil. Btu/hr (HHV)
Secondary Fuel see below / ______ mil. Btu/hr (HHV)
By-product Fuel gases & oil / 1900 mil. Btu/hr (HHV)

K. Fuels Discussion:

The major energy input to this process is the fuel to the cracking furnaces -- all of which comes from the gases and heavy oils generated in the process. Substantial steam (150,000 #/hr) is required from an offsite boiler, and this can be produced from any of several primary fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
30	Mostly in the South-Central U.S.	

M. Application Discussion:

It is expected that the majority of new ethylene plants will use this process (gas-oil cracking) as feedstock should be available from many sources such as domestic and imported petroleum, shale oil and synthetic oil from coal.

N. Preferred Economic Criteria: ______

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant will run continuously for as long as 2 or 3 years without a scheduled shutdown for maintenance. Critical equipment items (e.g. reactor, pumps, heat exchangers, etc.) will have one or more spare units which can replace an on-stream unit that may require maintenance. There will be unscheduled failures which will slow, or stop the plant on occasion; however, the plant will maintain smooth, uniform operation 90% of the time.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Ethylene from Gas Oil Cracking / 1500 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

7 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 12×10^6 tons/yr

In 2000 48×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

See attached sheet.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

See attached sheet

W. National energy consumed by this process

In 1978 300×10^{12} Btu/yr

In 1985 750×10^{12} Btu/yr

In 2000 1.1×10^{15} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

See attached sheet

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached sheet

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the previously defined basis the energy cost is approximately 14% of the total operating cost.

Ethylene from Gas Oil Cracking / 1500 tons/day

U. This plant has all features (waste treatment, waste heat recovery) expected to be necessary to comply with regulatory requirements and energy economics for the foreseeable future. The plant is designed to use the feedstocks expected to be available in 1985 and after.

V. Ethylene (and propylene also) is widely used as a chemical feedstock for many different chemicals and plastics which are in growing demand. Growth has been averaging more than 8%/yr. This will taper off in future years, however, production will still quadruple by 2000.

X. The average plant size today is about 950 tons per day. New plants are being built in sizes from 750 tons/day to 2000 tons/day. It is expected that the future typical plant size will be 1500 tons/day (1 billion lbs/yr). Economies of scale above this level are debatable.

Y. Major energy using operations in the plant are the cracking furnaces and the gas compressors. Other energy uses are in distilling and pumping.

CTAS Plant Data Sheet

A. Plant Name/Size: Vinyl Chloride Monomer/1000 tons/day from the balanced chlorination and oxychlorination processes

B. Products:

Product	lb/yr, etc.
Vinyl Chloride	1000 tons/day

C. Plant Kilowatt Requirements: Average 4000 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
180,000	@	150	condensate	200-300
27,000	@	300	"	300-320
	@			

E. Other Heat to Process (Describe):
The primary energy input to this process is the fuel (oil or gas) to the cracking (pyrolysis) furnace, in the amount of 480 MM Btu/hr.

F. Plant Hours of Operation at Average Conditions: 8300 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
1500	(refrigeration)			Elec.

H. Operational Considerations:
This plant is a single train continuous operation running 7 days per week. Extensive heat recovery is employed and the plant produces surplus 100 psig steam.

I. Waste Heat Streams:

lb/hr	Temp.	Description
15×10^6	100-120 F	Cooling water
$.7 \times 10^6$	400 F	Flue gas
56×10^3	330 F	100 psig steam

CTAS Plant Data Sheet

Plant Name/Size: Vinyl Chloride Monomer/1000 tons/day

J. Fuels: Primary Fuel Gas / 480 mil. Btu/hr (HHV)
Secondary Fuel see below / mil. Btu/hr (HHV)
By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion: Gas is the preferred fuel in this process to maintain good temperature control in the cracking furnace. It is feasible that oil could be used and perhaps coal, with proper furnace design. Approx. 240 MM Btu/hr of steam is used which could be generated using any of several fossil or synthetic primary fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
11	Mainly in the South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:
These plants will operate continuously 7 days per week with an annual shutdown of 1-2 weeks, for comprehensive maintenance. When the plant is running, any maintenance that slows production will be deferred as long as practicable. This plant will operate with a nominal on-stream factor of 95%.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Vinyl Chloride Monomer/1000 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Over \$750,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 3×10^6 tons/year

In 2000 12×10^6 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 50×10^{12} Btu/yr

In 1985 110×10^{12} Btu/yr

In 2000 160×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The average plant size today is over 700 tons/day and one plant is more than 1000 tons/day. Future typical plant size is expected to be approximately 1000 tons/day.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Vinyl Chloride Monomer/1000 tons/day

U. As environmental requirements become more stringent, new plants will use pure oxygen as a feed in place of air. This will reduce the vent gas flow and permit recovery of the small amounts of ethylene lost in the vent gas. Effect on the overall plant energy input will be small. No other significant changes in the process are expected.

V. Vinyl chloride is used almost entirely (97%) in various types of polymers for plastic products. It is used as PVC in a variety of products from shoe soles to plumbing systems. It is replacing many other products in common use and has been growing in production more than 10% per year. Demand will quadruple by 2000.

Y. Energy is used in this plant primarily in the form of gas in a cracking furnace and in the form of steam to the distilling columns. A smaller amount is used as electricity to the air compressor. Other operations using small amount of energy are pumping and gas quenching. Steam is generated from the heat of reaction from the oxychlorination reactor.

Z. Based on:

Capital	= \$70,000,000	Energy Costs = 13% of Total Operating Cost
Steam	= \$2.40/M lbs	
Fuel	= \$2.00/MM Btu	
Elec.	= 1.75¢/kWh	
Deprec.	= 10% S.L.	
Overhead & Supplies	= 110% of Op. Labor	
Operating Labor	= 7/shift @ \$9.30/hr	

CTAS Plant Data Sheet

A. Plant Name/Size: Styrene Monomer Production / 1500 tons/day

B. Products:

Product	lb/yr, etc.
Styrene	1500 tons/day
Toluene	70 "
Benzene	60 "
Fuel	90 "

C. Plant Kilowatt Requirements: Average 4400 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
320,000	@	75	0	
190,000	@	30		
	@			

E. Other Heat to Process (Describe):

A small amount of direct heat from gas or oil - 16 MM Btu/hr, is used to supplement the fuel (gas and oil) produced in the process and also used therein (~ 200 MM Btu/hr).

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
2700				Electricity

H. Operational Considerations:

This is a single train production operation with two cracking reactors in series, handling the continuous flow of the ethylene and steam feed.

I. Waste Heat Streams:

lb/hr	Temp.	Description
8×10^6	100 - 120 F	Cooling water
$.3 \times 10^6$	450 F	Flue gas
$.66 \times 10^6$	240 - 150 F	Reactor products (air cooled)

CTAS Plant Data Sheet

Plant Name/Size: Styrene / 1500 tons/day

J. Fuels:

Primary Fuel	oil/gas	/ 16	mil. Btu/hr (HHV)
Secondary Fuel	see below	/ (steam) 580	mil. Btu/hr ~~(HHV)~~
By-product Fuel	Hydrogen & waste/ products	200+	mil. Btu/hr (HHV)

K. Fuels Discussion:

The main energy input to this process is steam which is used both to provide heat to the process and to moderate the cracking reaction. Steam is also used in the distillation operations. The steam is superheated in a furnace fueled primarily by by-product fuels from the process; however, some additional primary fuel (either oil or gas) is required to meet the full heating requirements.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
6	Misc. U.S. locations	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant operates continuously around the clock 7 days a week. General maintenance is scheduled only during the annual shutdown of 2-3 weeks. Critical items of equipment requiring more frequent attention are installed in parallel so that one unit can be removed from service for repair or cleaning, while the plant continues to operate at full production.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

<u>CTAS Plant Data Sheet</u>

Plant Name/Size: Styrene / 1500 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$350,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 3.5×10^6 tons/yr

In 2000 10×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 35×10^{12} Btu/yr

In 1985 65×10^{12} Btu/yr

In 2000 90×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

--see attachment--

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Energy costs = 6.5% of the total production costs.

Styrene / 1500 tons/day

U. This process has no environmental hazards and no significant changes will be required to meet environmental requirements. There will be additional heat recovery incorporated into the process as time proceeds; however, the energy use shown here will be typical for the 1985-2000 time period.

V. Styrene is used in a wide variety of plastics and elastomers. End products vary from automobile tires to building insulation and have a fast growing demand. The use of styrene is expected to triple by 2000.

X. Average styrene plant size today is 950 tons/day (for 13 plants). One plant is almost 2000 tons/day. Typical future new plants are expected to be about 1500 tons/day.

Y. The major energy use is the process heater which superheats the steam. The superheated steam is mixed with the feed to the cracking reactors to provide heat input for the reaction. Distillation is also a major energy use. Significant energy is used by the fuel gas compressor. Waste heat is removed in the air cooled and water cooled condensers.

CTAS Plant Data Sheet

A. Plant Name/Size: Ethylbenzene from Benzene Alkylation / 1700 tons/day

B. Products:

Product	lb/yr, etc.
Ethylbenzene	1700 tons/day
Fuel	17 tons/day

C. Plant Kilowatt Requirements: Average 700 kW; Peak ________ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
220,000	@	600		
	@			
	@			

E. Other Heat to Process (Describe):

140 MM Btu of fuel (gas or oil) is required for process heat.

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
--				

H. Operational Considerations:

This process has been sized and designed to integrate with a 1500 tons/day styrene plant. Although it can be operated as a stand-alone unit, economics would require off-site utilization of the medium and low pressure steam produced from the heat recovery boilers. There are two parallel catalytic reactors in this process which operate on two week cycles. While one is on-stream, the other is being regenerated.

I. Waste Heat Streams:

lb/hr	Temp.	Description
198,000	25 psig	Steam from heat recovery boiler
124,000	150 "	" " " " "
245,000	100 - 120 F	Cooling water
177,000	450 F	Flue gas

CTAS Plant Data Sheet

Plant Name/Size: Ethylbenzene / 1700 tons/day

J. Fuels: Primary Fuel oil / gas / 140 mil. Btu/hr (HHV)
Secondary Fuel ____ / ____ mil. Btu/hr (HHV)
By-product Fuel ____ / ____ mil. Btu/hr (HHV)

K. Fuels Discussion:

The major energy input is the 600 psig steam. This steam can be generated using any of several different fuels suitable for steam boiler operation.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
7	Mostly in the South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria: ____

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant operates continuously, 24 hours per day, 7 days per week. Maintenance is scheduled to be accomplished during an annual shutdown of 2-3 weeks duration. There will be an occasional (infrequent) emergency shutdown.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Ethylbenzene / 1700 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)
More than $150,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.
--

T. What is the national capacity for producing this product

Now in 1978 4.5×10^6 tons/yr

In 2000 13×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

See attached sheet.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

See attached sheet.

W. National energy consumed by this process

In 1978	22×10^{12} Btu/yr	(all old process)
In 1985	Gross = 45×10^{12}, Net = 27×10^{12}	
In 2000	Gross = 65×10^{12}, Net = 10×10^{12}	(mostly new process)

X. Describe the typical size of this plant today and how that will change in 1985-2000.

See attached sheet.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.
See attached sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the previously defined basis, the cost of energy is 0% of the operating cost if we take full steam credit for the by-product steam. Without this credit, energy represents 5% of the total operating cost.

Ethylbenzene / 1700 tons/day

U. This process represents the latest state of the art and incorporates substantial waste heat recovery. The plant has no potentially harmful effluents to require future treatment. Future regulations may require special precautions in handling benzene, however, these should have little effect on energy use.

V. Ethylbenzene is used almost entirely in the production of styrene. Since styrene has diverse, fast growing markets, ethylbenzene is expected to have an increasing demand. Production will triple by 2000.

X. The average ethylbenzene plant today is about 1200 tons/day. The newest plant built will have a capacity of 1700 tons/day and this will be the nominal average new plant size for many years.

Y. This process consists of: feedstock vaporization, vapor phase reaction, product condensation and distillation. Feedstock heating (vaporization) and distillation require the major energy inputs. Waste heat is obtained from condensers on the reactor product and distilling column.

CTAS Plant Data Sheet

A. Plant Name/Size: Phenol (& Acetone) from Cumene Peroxidation / 600 tons/day

B. Products:

Product	lb/yr, etc.
Phenol	600 tons/day
Acetone	380 tons/day
Tar (fuel)	50 tons/day

C. Plant Kilowatt Requirements: Average 600 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
30,000	@	600		
270,000	@	200		
	@			

E. Other Heat to Process (Describe):

In some versions of this process the 600 psig steam is replaced by circulating Dowtherm[R] which is heated in a separate process heater using gas or oil fuels.

F. Plant Hours of Operation at Average Conditions: 8200 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
3000				Electricity

H. Operational Considerations:

The reactions involved in this process are exothermic and involve a potentially unstable intermediate product (cumene hydroperoxide). It is essential that reactor temperatures be held low (by cooling water) and provision made to dump the reactors if an abrupt temperature rise occurs.

I. Waste Heat Streams:

lb/hr	Temp.	Description
17×10^6	100 - 120 F	Cooling Water

CTAS Plant Data Sheet

Plant Name/Size: Phenol from Cumene / 600 tons/day

J. Fuels: Primary Fuel see below / mil. Btu/hr (HHV)
Secondary Fuel / mil. Btu/hr (HHV)
By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

The major energy input to this process is in the form of steam. Primary fuel for steam generation can be any of several fossil or synthetic fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
5	Misc. U.S. locations	?

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant operates continuously 7 days per week with a nominal annual shutdown of two weeks for general maintenance. Unscheduled shutdowns will bring the overall on-stream factor to about 93%.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Phenol from Cumene / 600 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

over $200,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1.5×10^6 tons/yr

In 2000 5×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

See attached sheet.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

See attached sheet.

W. National energy consumed by this process

In 1978 20×10^{12} Btu/yr

In 1985 45×10^{12} Btu/yr

In 2000 60×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

See attached sheet.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached sheet.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Based on: Capital = $45,000,000
Steam = $2.40/M lbs
Fuel = $2.00/MM Btu
Elec. = 1.75¢/kWh
Deprec. = 10% S.L.
Overhead & supplies = 110% of Op. Labor
Op. Labor = 7/shift @ $9.30/hr

Cost of energy = 9% of total operating cost

Phenol from Cumene / 600 tons/day

U. It will be necessary that essentially all acetone and phenol be removed (stripped) from the effluent water from these plants. The future plant will have more equipment and energy use devoted to effluent cleanup. This, however, will not affect energy use by more than a few percent.

V. Phenol is a versatile chemical used as an intermediate in the manufacture of other chemicals and also used in the manufacture of various resins for plastics. Three phenol derivatives: expoxies, caprolactum and polycarbonates have high growth potential. The use of phenol will more than triple by 2000.

X. The average plant size today in the U.S. is 375 tons/day, however, the two largest plants are about twice this size. The most recent new plant is approximately 600 T/D in size and it is expected that future new plants will stay about this size.

Y. The major energy using unit operation in this process is the distillation (product separation and purification) activity. Very little energy is used in the other unit operations - catalytic reactors, pumping and vacuum evaporation.

CTAS Plant Data Sheet

A. Plant Name/Size: Ethanol Synthesis / 800 tons/day

B. Products:

Product	lb/yr, etc.
Ethanol	800 tons/day
Fuel	40 tons/day

C. Plant Kilowatt Requirements: Average 3300 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
400,000	@	450	0	Condensate is used for process water
	@			
	@			

E. Other Heat to Process (Describe):

Fossil fuels (oil or gas) is used in a process heater to superheat the ethylene/water feed mixture entering the reactor (65 x 10^6 Btu/hr).

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
4000 hp				Electricity

H. Operational Considerations:

This is a single train, continuously operating plant with a nominal 90% on stream factor. On about an annual basis, the plant will be shut down for one or two weeks for general maintenance.

I. Waste Heat Streams:

lb/hr	Temp.	Description
23 x 10^6	100-120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Ethanol / 800 tons/day

J. Fuels:

Primary Fuel	gas/oil	/	67	mil. Btu/hr (HHV)
Secondary Fuel	steam	/	375	mil. Btu/hr (HHV)
By-product Fuel	gas	/	7	mil. Btu/hr (HHV)

K. Fuels Discussion:

Steam is the major energy input to this process and the primary fuel for the steam generation can be any of several fossil or synthetic fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
3	Misc. U.S. locations	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

As noted in item H, this plant operates on an around the clock, 7 days per week continuous basis. Shutdowns are infrequent. The plant may operate at a lower throughput or on an intermittent basis if sales or captive use of the product are restricted.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Ethanol / 800 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$250,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1×10^6 tons/yr

In 2000 2×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 18×10^{12} Btu

In 1985 24×10^{12} Btu

In 2000 30×10^{12} Btu

X. Describe the typical size of this plant today and how that will change in 1985-2000.

--see attachment--

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Ethanol / 800 tons/day

U. This is a relatively simple catalytic process and few changes are expected. No harmful effluents are produced. Catalyst improvement can be expected to bring some decrease in the temperature or pressure required for the reaction, which will bring some reduction in energy use.

V. Ethanol is an old product which is widely used as a solvent in both industrial and consumer products and as an intermediate in chemicals manufacturing. It has also been proposed as a synthetic liquid fuel. Use of ethanol will grow with the economy and is expected to double by 2000.

X. The average plant size today is 500 T/D. One plant (out of six total) is very large, however (over 1000 tons/day). Future new plants are expected to be larger than the present average and run about 800 tons/day.

Y. The major energy inputs for this process are to the distillation operations, to the feedstock superheater and to the gas compression. Pumping uses a small amount of energy. Heat is removed by cooling water in the distillation column condensers.

Z. Based on:

Capital = $45,000,000 Steam = $2.40/M lbs Fuel = $2.00/MM Btu Elec. = 1.75¢/kWh Deprec. = 10% S.L. Overhead & Supplies = 110% of Op. Labor Operating Labor = 4/shift @ $9.30/hr	Cost of energy = 13% of total operating cost

CTAS Plant Data Sheet

A. Plant Name/Size: Cumene/Benzene Alkylation / 700 tons/day

B. Products:

Product	lb/yr, etc.
Cumene	700 tons/day
Fuel	40 tons/day

C. Plant Kilowatt Requirements: Average 600 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
none	@			
	@			
	@			

E. Other Heat to Process (Describe):

Natural gas is used for direct process heat in the distillation process and also to heat the reactants up to required temperature levels.

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
none				

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
6.5×10^6	100-120 F	Circulating cooling water

CTAS Plant Data Sheet

Plant Name/Size: Cumene / 700 tons/day

J. Fuels: Primary Fuel natural gas or oil/ 100 mil. Btu/hr (HHV)
Secondary Fuel / mil. Btu/hr (HHV)
By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

This process uses Dowtherm® as a circulating heat transfer medium. The process furnace will normally be fired with gas or oil, however a coal fired process furnace would be feasible or even an oil fired combustion turbine with heat recovery.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
6	South Central & East Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Cumene plants are operated on a continuous "round the clock" basis with an annual shutdown (max. 2 weeks) for major maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

<u>CTAS Plant Data Sheet</u>

Plant Name/Size: Cumene / 700 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$130,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1.5×10^6 tons/yr

In 2000 4.8×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

see attached sheet

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

see attached sheet

W. National energy consumed by this process

In 1978 6.5×10^{12} Btu/yr

In 1985 10×10^{12} Btu/yr

In 2000 15×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

see attached sheet

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

see attached sheet

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the same basis previously deffned, the cost of energy for this process is 3% of the total operating cost.

Cumene / 700 tons/day

U. It is likely that heat recovery will be improved to reduce the amount of heat rejected in the cooling water. Also, natural gas as the primary fuel will be replaced by the fossil or synthetic fuels.

V. Cumene is used almost entirely in the manufacture of phenol and acetone. Growth in demand will parallel the growth of these two products. Both phenol and acetone demand will grow at about the norm of the chemical industry growth for a threefold increase by 2000.

X. The average plant size today is 380 tons/day (phenol). However, two plants have been expanded to approximately 1000 tons/day. Future expansion additions for this product will average about 700 tons/day.

Y. Principal unit operations are the catalytic reactor, distillation and associated heat exchange. A process heater to supply hot Dowtherm[R] requires the major energy input.

C-4

CTAS Plant Data Sheet

A. Plant Name/Size: Isopropanol by Direct Hydration / 1000 tons/day

B. Products:

Product	lb/yr, etc.
Isopropanol	1000 tons/day
Fuel	20 tons/day

C. Plant Kilowatt Requirements: Average 3600 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
350,000	@	150 ,	,	
	@	,	,	
	@	,	,	

E. Other Heat to Process (Describe):

Oil or gas is used in a process heater at the rate of 4×10^9 Btu/day to superheat the reactor feed streams.

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
2000				Elec.

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
17×10^6	100 - 120 F	Cooling water
600,000	400 F	Flue gas

CTAS Plant Data Sheet

Plant Name/Size: Isopropanol by Direct Hydration / 1000 tons/day

J. Fuels: Primary Fuel Gas or Oil / 165 mil. Btu/hr (HHV)
Secondary Fuel Steam / 415 mil. Btu/hr (HHV)
By-product Fuel Gas / 35 mil. Btu/hr (HHV)

K. Fuels Discussion:

Most of the energy input is in the steam, which can be produced from any of several fossil or synthetic fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
3	South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant will operate continuously with a 90% or better on-stream factor. The plant will shut down about once per year for major maintenance.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Isopropanol by Direct Hydration / 1000 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)
$150,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1.2×10^6 tons/year

In 2000 3×10^6 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

No significant process changes are expected.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Isopropanol is used in the production of acetone and for solvent and medicinal purposes. Growth was temporarily slowed as about one-half of the acetone market was taken over by another process. Future growth will be about parallel to the growth of the economy (3%/year).

W. National energy consumed by this process

In 1978 3×10^{12} Btu/yr

In 1985 6×10^{12} Btu/yr

In 2000 11×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Average size of the five U.S. plants producing isopropanol today is 685 T/D. It is expected that these plants will be replaced and or expanded with 1000 T/D plants using the direct hydration process.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Isopropanol / 1000 tons/day

Y. Major unit operations are the gas compression catalytic reaction, distillation and pumping. Distillation is the major energy use together with preheating the reactor feed.

Z. Based on: Capital = $45,000,000
Steam = $2.40/M lbs
Fuel = $2.00/MM Btu
Deprec. = 10% S.L.
Overhead & Supplies = 110% of Op. Labor
Operating Labor = 4/shift @ $9.30

Energy Input = 15% of Operating Cost

CTAS Plant Data Sheet

A. Plant Name/Size: Methanol Synthesis / 1500 tons/day

B. Products:

Product	lb/yr, etc.
Methanol	1500 tons/day
Carbon Dioxide	1030 tons/day

C. Plant Kilowatt Requirements: Average 1500 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
110,000	@	1250	100	21% = 360 F @ 150 psig 79% = 120 F (condensate)
23,000	@	150	0	

E. Other Heat to Process (Describe):

Much of the heat for the process is derived from the partial oxidation of the oil used for feedstock to make the synthesis gas.

F. Plant Hours of Operation at Average Conditions: 7880 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
10,000				Steam

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
9,400,000	120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Methanol Synthesis / 1500 tons/day

J. Fuels:

Primary Fuel	/ none	mil. Btu/hr (HHV)
Secondary Fuel	/ 300 +	mil. Btu/hr (HHV)
By-product Fuel	/	mil. Btu/hr (HHV)

K. Fuels Discussion:

Feedstock oil is partially oxidized to produce carbon monoxide and hydrogen. This releases heat which can be converted to steam for use elsewhere in the process.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
8	Mostly in the South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

The plant is operated on a continuous basis with a planned shutdown about once per year for two weeks. An occasional unscheduled shutdown may reduce the on-stream time to 90%.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Methanol Synthesis / 1500 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$500,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 4.5×10^6 tons/yr

In 2000 13×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

-- see attachment--

W. National energy consumed by this process

In 1978 ______

In 1985 ______ no fuel used per se.

In 2000 ______

X. Describe the typical size of this plant today and how that will change in 1985-2000.

--see attachment--

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

No fuel used per se.

Methanol Synthesis / 1500 tons/day

U. This process wastes a lot of heat ($\sim 180 \times 10^6$ Btu/hr) in the cooling water from the reactors. It is likely that this heat will be used to make steam for use in other processes or for power generation for export.

V. Methanol is used as an organic chemical raw material and as a solvent. Use is expected to grow much faster than the general economy.

X. The average plant size today is 1000 tons/day. This will increase to 1500 T/D.

Y. The plant has a reactor to produce synthesis gas and also the synthesis reactor --- both reactors produce heat as described elsewhere. Other unit operations include gas compression (large energy user), distillation and misc. pumping.

CTAS Plant Data Sheet

A. Plant Name/Size: Chlorine & Caustic Soda from Diaphragm Cells / 1000 tons/day

B. Products:

Product	lb/yr, etc.
Chlorine	1000 tons/day
Caustic soda	1130 "
Hydrogen	28 "

C. Plant Kilowatt Requirements: Average ________ kW; Peak ________ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
175,000	@	100		
90,000	@	20		
	@			

E. Other Heat to Process (Describe):

Some heat is generated by electrolysis of the salt solution. This is partially recovered by heat exchange to preheat the incoming salt solution.

F. Plant Hours of Operation at Average Conditions: 8500 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
--				

H. Operational Considerations:

--

I. Waste Heat Streams:

lb/hr	Temp.	Description
5.4×10^6	100 - 120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Chlorine-Caustic Soda / 1000 tons/day

J. Fuels: Primary Fuel See below / mil. Btu/hr (HHV)
Secondary Fuel Steam / 312 mil. Btu/hr (HHV)
By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:
Energy is used in the form of electricity for electrolysis of the salt solution and steam for evaporation and concentration of the caustic soda product. Primary fuel could be any fuel suitable for steam and power generation.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
13	Where electricity will have the lowest cost	High

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:
Chlorine/caustic plants run continuously as long as sales exist for the products. Annual scheduled maintenance would require about a one week shutdown and unscheduled interruptions would bring the plant down a few more days each year. Individual cells and other plant facilities can be maintained by being taken off stream without stopping the entire plant.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Chlorine-Caustic Soda / 1000 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Over 1.25 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 12,500,000 tons/year

In 2000 22,500,000 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Changes to be expected in this process will reduce the energy consumption. It is likely that new cell designs will result in a more concentrated caustic soda product which will reduce some of the steam requirement.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Chlorine and caustic soda are basic chemical commodities used in the manufacture of many other products throughout the economy. Both are well past their major growth rates but they will continue to grow somewhat slower than the general economy.

W. National energy consumed by this process

In 1978 180×10^{12} Btu/yr

In 1985 240×10^{12} Btu/yr

In 2000 300×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Some of the 68 existing chlorine/caustic plants are quite old and small size. Average size overall is 180 tons Cl_2/day. Newer plants - so called "world scale plants" - are close to 1000 tons/day and this is the size that will be built in the 1985-2000 period

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Chlorine-Caustic Soda / 1000 T/D

Y. Electrolysis cells are the major energy use with multiple effect evaporators using almost as much energy. Other unit operations are filtration, mixing and pumping.

Z. Based on: Capital = \$105,000,000
Steam = \$2.40/M lbs
Elec. = 1.75¢/kWh
Deprec. = 10% S.L.
Overhead & Supplies = 110% of Op. Labor
Operating Labor = 9/shift @ \$9.30/yr

Energy cost = 44% of total operating cost

CTAS Plant Data Sheet

A. Plant Name/Size: Cryogenic Oxygen/Nitrogen / 2000 tons/day

B. Products:

Product	lb/yr, etc.
Oxygen	2000 tons/day
Nitrogen	7000 tons/day

C. Plant Kilowatt Requirements: Average 34,000 kW; Peak essentially the same kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
none	@			
	@			
	@			

E. Other Heat to Process (Describe):

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
35,000				Electricity
12,000				"

H. Operational Considerations:

Essentially all of the energy input to this process is the power for the compressors. It is feasible that these compressors can be driven with a combustion turbine or a steam turbine as well as the conventional electric motor.

I. Waste Heat Streams:

lb/hr	Temp.	Description
none		

CTAS Plant Data Sheet

Plant Name/Size: Cryogenic Oxygen / 2000 tons/day

J. Fuels: Primary Fuel Electricity / 34,000 kW mil. Btu/hr (HHV)

Secondary Fuel ______ / ______ mil. Btu/hr (HHV)

By-product Fuel ______ / ______ mil. Btu/hr (HHV)

K. Fuels Discussion:

If an alternate driver is used for the compressor, many fuels options are feasible -- coal, gas or oil.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
52	Throughout the U.S.	Good - if integrated with other plants

M. Application Discussion:

These oxygen plants will almost all be built in conjunction with other oxygen using processes, e.g. coal gasification, steel production, methanol prou. on, etc.

N. Preferred Economic Criteria: ______

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Oxygen plants run continuously with very little downtime. Planned maintenance is nominally scheduled for 5 days once every two years.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Cryogenic Oxygen / 2000 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Over 1.5 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 16×10^6 tons/yr

In 2000 48×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 22×10^{12} Btu/yr

In 1985 33×10^{12} Btu/yr

In 2000 66×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

--see attachment--

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Cryogenic Oxygen / 2000 tons/day

U. Very few changes in this process are anticipated. As mentioned previously where advantageous circumstances exist, combustion turbines or steam turbines can be substituted and the appropriate fuels used.

V. The demand for oxygen has grown faster than the general economy for several years and this trend will continue. Synthetic fuels manufacture will use large quantities of oxygen in the future. Demand will triple by the year 2000.

X. The maximum size for proven technology today is 2000 T/D of oxygen. Larger single train plants would require new prototype valves, compressors, distilling columns, etc. which are not being manufactured. Thus 2000 T/D will be a typical largest module for several years to come.

Y. Gas compression accounts for almost all of the energy use. Turbo expanders are used for cooling and distillation is used.

Z. A standard value used in the industrial gas industry is that energy (power) input represents 45% of the operating cost. Another 45% covers depreciation and other capital costs and 10% is for operating and maintenance costs.

CTAS Plant Data Sheet

A. Plant Name/Size: Low Density Polyethylene Resin / 1000 tons/day

B. Products:

Product	lb/yr, etc.
Polyethylene Polymer	1000 tons/day
Fuel	30 tons/day

C. Plant Kilowatt Requirements: Average 55,000 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
16,000	@	400		
	@			
	@			

E. Other Heat to Process (Describe):

None

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
33,000				Elec.
18,000				"
15,000				"

H. Operational Considerations:

Most of the energy input to this process is for power to the compressors. Very high pressures (30,000 - 40,000 psi) are required. Much of the waste heat (1/3) is derived from interstage cooling of the compressed gas with temperatures from 215-280 F. The rest of the waste heat comes from cooling the reactors at temperatures of 350 - 500 F.

I. Waste Heat Streams:

lb/hr	Temp.	Description
6×10^6	100-120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Low Density Polyethylene / 1000 tons/day

J. Fuels: Primary Fuel see below / mil. Btu/hr (HHV)

Secondary Fuel Steam / 19 mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

No fuel as such is used in this process. Steam and electricity are required, each of which can be produced with a variety of fuels. It is also feasible that some of the steam required in this process could be produced in heat recovery boilers. Also, instead of electricity, steam could be used to drive the compressors.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
15	Mostly in South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This type of plant (large, single train) will have an annual two or three week shutdown for maintenance. At random intervals (biweekly to bimonthly) there will be one day shutdowns to change a component or shift to a different grade of product.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Low Density Polyethylene / 1000 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

More than 2 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 3×10^6 tons/year

In 2000 12×10^6 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Major end use for Low Density Polyethylene is in a wide variety of plastic materials. Annual growth is very high (~10%/yr) and there will be a fourfold increase in demand by the year 2000.

W. National energy consumed by this process

In 1978 18×10^{12} Btu/yr

In 1985 38×10^{12} Btu/yr

In 2000 60×10^{12} Btu/yr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Average plant size is 500 tons/day at present. Newest single train plants are 1000 T/D and these will be standard in the 1985-2000 period.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Low Density Polyethylene / 1000 tons/day

U. It is likely that the ethylene feedstock for this process will be derived from fossil and synthetic oils rather than natural gas. There will probably be a reduction in the pressures required for the polymerization thereby reducing the power required for compression.

Y. Major energy consumption is in the gas compressors, waste energy comes from heat exchange in the compressor coolers and the reactors. Other unit operations are extrusion, drying and solid materials handling.

Z. Based on: Capital = $159,000,000
Elec. = 1.75¢/kWh
Steam = $2.40/1000 #
Deprec. = 10% S.L.
Overhead & Supplies = 110% of Op. Labor
Operating Labor = 7/shift @ $9.30/hr

Energy = 6.5% of Operating Cost

CTAS Plant Data Sheet

A. Plant Name/Size: Styrene-Butadiene Rubber, Emulsion Process / 350 tons/day

B. Products:

Product	lb/yr, etc.
S-B Rubber	350 tons/day

C. Plant Kilowatt Requirements: Average 7500 kW; Peak + 10% kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
35,000	@	100	0	
	@			
	@			

E. Other Heat to Process (Describe):

Electricity provides the other energy input to this process.

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
3000				Elec.

H. Operational Considerations:

S-B Rubber plants consist of multiple reactor trains operating in parallel. This is to keep the size small enough that temperature and mixing in the reactors can be carefully controlled.

I. Waste Heat Streams:

lb/hr	Temp.	Description
2×10^6	100-120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: S-B Rubber / 350 tons/day

J. Fuels: Primary Fuel -- / mil. Btu/hr (HHV)
Secondary Fuel -- / mil. Btu/hr (HHV)
By-product Fuel -- / mil. Btu/hr (HHV)

K. Fuels Discussion:

Energy inputs are in the form of steam and electricity. Primary fuel to produce the steam and electricity can be any of several fossil or synthetic fuel options.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
8	Mostly in the South Central U.S.	--

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant will operate continuously 24 hours per day, 7 days per week. Individual production trains can be shut down for maintenance or product change without affecting operation of the rest of the plant. Steam use on each train is intermittent and peak demand for the plant may be twice the average hourly demand. The entire plant may be shut down for general maintenance about once per year. On stream factor for the plant is about 90 %.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: S-B Rubber / 350 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$400,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1.5×10^6 tons/yr

In 2000 3×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 7×10^{12} Btu/yr

In 1985 9×10^{12} Btu/yr

In 2000 13×10^{12} Btu/hr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

--see attachment--

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

S-B Rubber / 350 tons/day

U. There will be few changes in this process over the next 20 years. Required temperature levels are low (<200 F) and there is little opportunity for waste heat recovery. Environmental pollution controls should not affect the process significantly nor alter the energy use.

V. This is the principal source of rubber for the U.S. economy. S-B rubber is widely used in automobile tires and in other commercial rubber products. Use is expected to grow with the economy and to double by the year 2000.

X. Average plant size today is about 350 tons/day (13 plants). One plant is larger than 1000 tons/day. Plant size can be increased incrementally by adding reactor trains. It is expected that the typical new plant of 1985-2000 will be 350 tons/day.

Y. Refrigeration (compression) and stirred vessels (mixing) account for most of the electricity use. Steam is used largely for steam distillation. Other unit operations are pumping, drying, extruding and materials handling.

Z. Based on: Capital = \$56 million
Elec. = 1.75¢/kWh
Steam = \$2.40/M lbs
Fuel = \$2.00/MM Btu
Deprec. = 10% S.L.
Overhead/Supplies = 110% of Op. Labor
Op. Labor = 16/shift @ \$9.30/hr.

Energy Cost = 2.5% of Operating Cost

CTAS Plant Data Sheet

A. Plant Name/Size: Polyester Fiber Production / 250 tons/day

B. Products:

Product	lb/yr, etc.
Polyester Fibers	250 tons/day
Methanol	80 "

C. Plant Kilowatt Requirements: Average 32,000 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
30,000	@	250		
	@			
	@			

E. Other Heat to Process (Describe):

Circulating Dowtherm[R] is used for part of the heat to this process. Primary fuel for this use is either oil or gas in the amount of 57 MM Btu/hr.

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver

H. Operational Considerations:

This plant consists of a number of parallel production trains which can shut down and start up independently. However, the overall plant will operate continuously.

I. Waste Heat Streams:

lb/hr	Temp.	Description
10×10^6	100 - 120 F	Cooling water
750,000	90 - 110 F	Fiber products - air cooled

CTAS Plant Data Sheet

Plant Name/Size: Polyester Fiber / 250 tons/day

J. Fuels:

Primary Fuel	gas / oil	57	mil. Btu/hr (HHV)
Secondary Fuel	(steam)	34	mil. Btu/hr (HHV)
By-product Fuel			mil. Btu/hr (HHV)

K. Fuels Discussion:

The primary fuel is supplied to a Dowtherm[R] heater and can be either a gas or liquid fuel. The secondary fuel is used to generate steam and can be any of several fuels suitable for boiler operation. Electricity, which is the major energy input to this plant, also can be produced from any of several different fuels.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
10	East South Central U.S.	--

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant will operate continuously, 24 hours per day, 7 days per week, however, individual sections can be shut down for a process change or maintenance without affecting the rest of the plant. Cyclical operation or maintenance of individual production trains is scheduled so as to minimize load swings on the utilities.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

Steam and electricity load variations of $\pm$10-15% can occur from one working shift to another when a production train is shut down or started up.

CTAS Plant Data Sheet

Plant Name/Size: Polyester Fiber / 250 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

over 2 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1.5×10^6 tons/yr

In 2000 4.5×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

See attached sheet

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

See attached sheet

W. National energy consumed by this process

In 1978 30×10^{12} Btu/yr

In 1985 55×10^{12} "

In 2000 75×10^{12} "

X. Describe the typical size of this plant today and how that will change in 1985-2000.

See attached sheet

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached sheet

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the same basis given previously, the cost of energy is 5% of total operating cost.

Polyester Fiber / 250 tons/day

U. This is an energy intensive process in terms of energy input per ton of product and it is expected that substantial improvement in the thermal efficiency will be achieved. This will take the form of waste heat recovery and more efficient equipment, however, the basic process will not change significantly. Energy intensity reduction up to 35-40% will be obtained.

V. Polyester fiber demand has had very fast growth (>10%/yr) in recent past years. It is now slowing as the market saturates. Substantial demand growth will however continue as polyester fabrics are still in increasing demand. Production is expected to triple by 2000.

X. The average plant size today is 200 tons/day. Capacity growth for the next few years will be mainly incremental additions to existing plants. After 1985, new plant construction will be at the 250 ton/day size.

Y. The largest energy requirement is for electricity in the fiber extruders (spinning and drawing) operationand electricity for the air conditioning required by this portion of the process. Much heat is also used in the distilling columns and reactors. Other operations are mixing, melting and pumping.

CTAS Plant Data Sheet

A. Plant Name/Size: Nylon 66 Fiber Production / 150 tons/day

B. Products:

Product	lb/yr, etc.
Nylon Fiber	150 tons/day

C. Plant Kilowatt Requirements: Average 11,000 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
23,000	@	30		
	@			
	@			

E. Other Heat to Process (Describe):

Some units in this process require temperatures higher than can be conveniently provided with steam. For these units, circulating Dowtherm[R] is used at temperatures of 500 - 540 F.

F. Plant Hours of Operation at Average Conditions: 8760 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver

H. Operational Considerations:

This is a continuous process plant with multiple parallel production trains, each of which can be started up, stopped and maintained independently. Also portions of each train can be isolated by accumulating buffer stocks of intermediate material to keep the downstream portion of the train operating. Thus, overall energy requirements are not subject to wide fluctuations.

I. Waste Heat Streams:

lb/hr	Temp.	Description
2.5×10^6	100-120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Nylon 66 Fiber / 150 tons/day

J. Fuels:

Primary Fuel	see below	/ 25 (steam)	mil. Btu/hr (HHV)
Secondary Fuel	" "	/ 23 (Dowtherm[R])	mil. Btu/hr (HHV)
By-product Fuel		/	mil. Btu/hr (HHV)

K. Fuels Discussion:

Approx. one-half of the heat input is in the form of steam which can be generated using any of several different fuels. The other one-half of the heat is supplied by circulating Dowtherm[R] heat transfer fluid and again for this, any of several different primary fuels can be used in the combustion furnace. Much of the electrical energy input is used for air conditioning in the spinning and drawing operations area.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
8	Mostly in the South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant has a continuous duty cycle with relatively small disturbances as components of the various production trains are shut down or started up. Maintenance is performed when individual production components are out of service, without affecting operations in the rest of the plant.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Nylon 66 Fiber / 150 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Over 1 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 1×10^6 tons/yr

In 2000 2×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

see attached sheet

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

see attached sheet

W. National energy consumed by this process

In 1978 14×10^{12} Btu/yr

In 1985 20×10^{12} "

In 2000 25×10^{12} "

X. Describe the typical size of this plant today and how that will change in 1985-2000.

See attached sheet

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See attached sheet

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the same basis given previously, energy costs represent on the average less than 2% of total operating cost. This will vary with the type of product fiber produced.

Nylon 66 Fiber / 150 tons/day

U. Few changes are anticipated for this process. There are no significant environmental problems. Natural gas as a primary fuel will likely be replaced by oil or coal. Additional heat recovery systems will be installed to improve the thermal efficiency.

V. Nylon 66 is widely used in textiles and industrial plastic products where high tensile strength or abrasion resistance is needed. The market has been growing faster than the general economy as Nylon 66 products replaces other products. The production will double by 2000.

X. The typical plant size today is about 150 tons/day capacity. Two or three plants range up to 300 tons/day. New growth will be in incremental additions to existing plants. After 1985 such additions are expected to be in 150 tons/day increments.

Y. The major energy use in this process is the electricity input to the fiber extrusion (spinning & drawing) operation, including the required air conditioning. Much heat is used in the nylon salt evaporator. A third major energy use is the Dowtherm[R] heat to the polycondensation reactor. Other operations are pumping and materials handling.

CTAS Plant Data Sheet

A. Plant Name/Size: Ammonia Synthesis / 1200 tons/day

B. Products:

Product	lb/yr, etc.
Ammonia	1200 tons/day
Carbon Dioxide	1600 tons/day

C. Plant Kilowatt Requirements: Average 3500 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
560,000	@	1500	100%	
80,000	@	600	-	
	@			

E. Other Heat to Process (Describe):

The major energy input is 12×10^9 Btu/day of direct fuel to the reformer furnace.

F. Plant Hours of Operation at Average Conditions: 8400 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
12,700		Not significant		Steam
25,000		"	"	"
8,500		"	"	"

H. Operational Considerations:

All of the steam load is met with steam obtained from waste heat boilers on the reformer furnace and reactors.

I. Waste Heat Streams:

lb/hr	Temp.	Description
24×10^6	100-120 F	Cooling water
500,000	400 F	Flue gas

CTAS Plant Data Sheet

Plant Name/Size: Ammonia Synthesis / 1200 tons/day

J. Fuels: Primary Fuel gas/oil / 500 mil. Btu/hr (HHV)

Secondary Fuel / mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

A wide range of fuels can be used, however the reformer furnace msut be designed for the specific fuel to be used.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
17	Mainly South Central U.S.	

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Continuous operation/keep the plant running.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

Not appropriate

CTAS Plant Data Sheet

Plant Name/Size: Ammonia Synthesis / 1200 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

over 1 billion dollars

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978	18×10^6 tons/yr
In 2000	34×10^6 "

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Natural gas as a fuel and feedstock will be replaced by oil, and in some cases coal. Increased heat recovery will reduce the fuel consumption.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

This process is used almost entirely in the production of ammonia for fertilizers. Production for this use is expected to double by 2000 based on anticipated crop production.

W. National energy consumed by this process

In 1978	300×10^{12} Btu/yr
In 1985	370×10^{12} "
In 2000	420×10^{12} "

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The average size of existing plants is 220 tons/day. Newer plants are 1000 T/D and larger. Typical plant size for 1985 and later will be 1200 tons/day.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. The major energy users are the reformer furnace and gas compressors. Other unit operations are: catalytic reactor, gas absorption refrig. and distillati

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the same basis as given previously, energy costs are 21% of total operating cost.

Ammonia Synthesis / 1200 tons/day

U. Natural gas as a fuel and feedstock will be replaced by oil and in some cases by coal. Increased heat recovery will reduce the fuel consumption.

V. The pr: .ess is used primarily to produce ammonia for fertilizer use. This market will almost double between 1978 and 2000.

X. Average size of existing plants is 220 tons/day. Newer plants are 1000 tons/day and state of the art which will be typical 1985+ construction is 1200+ tons/day.

Y. The major energy users are the reformer furnace and the gas compressors. Other unit operations are catalytic reactors (exothermic), gas absorption refrigeration and distillation.

Z. Based on:

Capital = $75,000,000		Fuel = 21% of Operating Cost
Fuel = $2.00/MM Btu		
Deprec. = 10% S.L.		
Supplies & Overhead = 110% of Op. Labor		
Operating Labor = 5/shift @ $9.30/yr		

CTAS Plant Data Sheet

A. Plant Name/Size: Phosphoric Acid - Wet Process / 1000 tons/day

B. Products:

Product	lb/yr, etc.
Phosphoric Acid (Ortho)	500 ton/day (P_2O_5)
" " (Super)	500 " "
Gypsum	5600

C. Plant Kilowatt Requirements: Average 4000 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
65,00	@	25		
27,000	@	125		
	@			

E. Other Heat to Process (Describe):

A natural gas fueled submerged gas evaporator requires 125 MM Btu/hr of fuel input. Reactor temperatures (160 - 175 F) are maintained by the heat of reaction between the phosphate rock and the sulfuric acid.

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
750	(air compressor)			Electricity

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
7.3×10^6	100 - 120 F	Cooling water

CTAS Plant Data Sheet

Plant Name/Size: Phosphoric Acid / 1000 tons/day

J. Fuels: Primary Fuel gas / oil / 65 mil. Btu/hr (HHV)

Secondary Fuel / mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

Much energy in the form of electricity and steam is required for this process. Fuels for the generation of electricity and steam can be any of several fossil or synthetic fuels. The primary fuel is used in a submerged gas evaporator and must be a clean burning fuel such as natural gas as distillate oil. Other types of evaporators using steam or circulating Dowtherm[R] could be alternatively substituted.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
8	Most of these plants will be in Florida.	--

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

This plant operates on a continuous 24 hour per day, 7 days per week basis. It is expected to have a 90% on-stream factor. As much as possible, maintenance is deferred or scheduled to the annual shutdown for 2-3 weeks.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Phosphoric Acid / 1000 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$250,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 9×10^6 tons/yr

In 2000 18×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

see attached sheet

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

The product is used almost entirely in fertilizer manufacture and growth is dependent upon agricultural crop production. Demand is expected to double by 2000.

W. National energy consumed by this process

In 1978 35×10^{12} Btu/yr

In 1985 48×10^{12} "

In 2000 60×10^{12} "

X. Describe the typical size of this plant today and how that will change in 1985-2000.

The average plant size today is about 800 tons/day capacity. Newer plants range up to 1000 T/D. Future plant construction is expected to average 1000 T/D in size.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

see attached sheet

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Using the same basis deffned previously, energy costs are 7.5% of total operating costs.

Phosphoric Acid / 1000 tons/day

U. It is expected that the future new plants will process rock with a lower phosphate content and increased beneficiation of the rock will be required. Little change in the basic process is expected, however there will be improvements in heat recovery and energy utilization to reduce energy intensity.

Y. Unit operations consist of air blown reactor tanks, filtration, evaporation, pumping and materials handling. Energy use is diffused over all operations.

CTAS Plant Data Sheet

A. Plant Name/Size: Carbon Black by Arom. Oil Pyrolysis / 300 tons/day

B. Products:

Product	lb/yr, etc.
Carbon black	300 tons/day

C. Plant Kilowatt Requirements: Average 4000 kW; Peak 5000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
20,000	@	50		
	@			
	@			

E. Other Heat to Process (Describe):

Primary fuel to the reactor = 2.7×10^9 Btu/day

F. Plant Hours of Operation at Average Conditions: 7900 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver

H. Operational Considerations:

Plant consists of a number (20-30) of individual reactors which normally cycle a daily to weekly basis for adjustment and maintenance. An off gas is produced from the reactors -- this gas has a 50-60 Btu/cu.ft. combustion value.

I. Waste Heat Streams:

lb/hr	Temp.	Description
520,000	400 F	Off gas (flue gas) from reactors

CTAS Plant Data Sheet

Plant Name/Size: Carbon Black /300 tons/day

J. Fuels: Primary Fuel ______ / 112 mil. Btu/hr (HHV)
Secondary Fuel ______ / ______ mil. Btu/hr (HHV)
By-product Fuel ______ / ______ mil. Btu/hr (HHV)

K. Fuels Discussion:
Oil or gas can be used for primary fuel. A heavy aromatic gas oil is introduced into the high temperature zone of the primary combustion where it is pyrolized to produce the carbon product -- some of the gas oil feed is oxidized and produces heat.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
9	Misc. U.S. locations	

M. Application Discussion:

N. Preferred Economic Criteria: ______

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:
There are 4 reactors per unit and 6 units per plant. Reactors are shut down and adjusted (to obtain various grades of carbon black) on a daily or weekly basis. Probably not more than one unit w ll be down at the same time. The overall plant will be operating 90 percent of the time.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Carbon Black / 300 tons/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

$300,000,000

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978	2×10^6 tons/yr
In 2000	3.3×10^6 tons/yr

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978	18×10^{12} Btu/yr
In 1985	20×10^{12} Btu/yr
In 2000	24×10^{12} Btu/hr

X. Describe the typical size of this plant today and how that will change in 1985-2000.

--see attachment--

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

--see attachment--

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

--see attachment--

Carbon Black / 300 tons/day

U. It is likely that CO (carbon monoxide) boilers will be installed to recover the heating value of the off gas. It may be desirable to have oxygen enrichment of the combustion air to increase the heating value of the off gas. If steam from the CO boiler is used to produce electricity, the plant will produce 5 times as much electricity as it uses.

V. The main use of carbon black is in rubber products and pigments. Growth will be strongly related to growth of the automobile usage.

X. Typical average plant size today is 150 tons/day. By 1985-2000 typical size will be 300 tons/day.

Y. The major energy is the primary fuel and feedstock to the reactor. Other unit operations are bag filters, mechanical conveyors, pelletizers, pulverizers and drying.

Z. Based on: Capital = $33,000,000
Fuel = $2.00/MM Btu
Deprec. = 10% S.L.
Supplies & Overhead = 110% of Op. Labor
Operating Labor = 7 men/shift @ $9.30/hr

Fuel = 21% of operating cost (primary fuel only).

If we consider that one-half of the feedstock represents fuel, then total fuel is 43% of operating cost.

7. Petroleum and Coal Products (SIC-29)

7.1 General

Within SIC-29, petroleum refining accounts for more than 95% of the energy use. Accordingly, we confine our analysis and discussion to this one industry.

7.2 Petroleum Refining

The petroleum refining industry is a highly complex, multi-product operation which uses many processes to convert crude oil into usable products. Technological changes over the past 25 years have been deep and rapid, with the result of increasing the number of light petroleum products and improving product quality. The domestic refinery has shifted significantly from heavy fuels to the production of lighter products such as gasoline, distillate fuels and petrochemical feedstocks.

No two refineries are exactly alike. Each refinery is designed to utilize a specific range of crude oils and has various degrees of flexibility to alter product yields. Refineries are becoming increasingly complex as more difficult crudes are processed and more exacting specifications on product and environmental quality are met. To characterize the petroleum refining industry in terms of cogeneration possibilities is a difficult task because of the extreme flexibility of processes and supporting systems. In this investigation the primary processes have been examined and then integrated into prototypical refineries. The data sheets have been developed to characterize typical small, medium, and large refineries.

The most energy intensive processes are alkylation, thermal cracking, fluid catalytic reforming and coking. Thermal cracking is now almost obsolete, having been replaced largely by catalytic cracking. Alkylation and catalytic reforming have been growing as a percent of crude capacity. This trend will probably continue because both processes can be used to produce high octane unleaded gasoline, which will become increasingly important in the future as the use of lead alkyls (e.g. tetraethyl lead) is reduced.

7.2.0 Energy Conservation

The opportunities for waste heat recovery and improvements in the design of existing energy consuming systems in the refining industry are

substantial. Unlike the conservation measures mentioned previously, most of these require some form of capital outlay. Among the more important techniques are:

a. heat recovery from stack gases;
b. optimizing heat exchanger configuration;
c. extending the surface area of heat exchangers;
d. improving pump, drivers and piping characteristics;
e. improving insulation;
f. power recovery from steam pressure reductions;
g. improved steam traps and condensate units;
h. CO boilers on catalytic cracking and fluid coking units;
i. power recovery from compressed fluids; and,
j. vapor recompression

From an energy conservation standpoint the most important measures are heat recovery from stack gases and optimizing heat exchange to reduce transfer to cooling water or air.

(1) <u>Heat recovery</u>

Heat recovery from stack gases can be accomplished by:

a. install tubes in the flue gas stack and pass process liquid through the tubes to absorb heat; and
b. use exhaust gases to preheat combustion air.

The use of stack gases to heat process liquid is widely practiced. However, there still exist many opportunities to improve the degree of heat recovery by this method. The use of combustion air preheater is an alternative as is generation of steam.

Air preheaters are fairly simple in design, and are already in substantial use. Based on industry sources roughly 10-20% of the potential has already been accomplished. Equipment manufacturers claim that boiler fuel savings of up to 25% can be accomplished through the use of preheaters. Industry estimates are generally in the 10 to 15% range. Preheaters are not without drawbacks. In some air sheds in which nitrogen oxides are a problem the use of air preheaters may be restricted. The higher flame temperatures encountered with preheat generate increased nitrogen oxides which may result in a prohibition against their use.

(2) Power Recovery Systems

The use of power recovery systems can also lead to substantial energy savings. Useful work can be recovered from steam, waste flue gases and process streams.

Typical examples would include:

a. Steam pressure reduction by let-down through a turbine to drive a process pump. The exhaust steam in turn being used for process heat;
b. Steam let-down through a turbine to drive an electric generator;
c. Steam let-down through a thermocompressor to recompress low pressure waste steam to some intermediate level;
d. Use of catalytic cracking regenerator gas to drive turbines and generate power, and
e. Use of hydraulic turbines to recover energy from high pressure liquid streams.

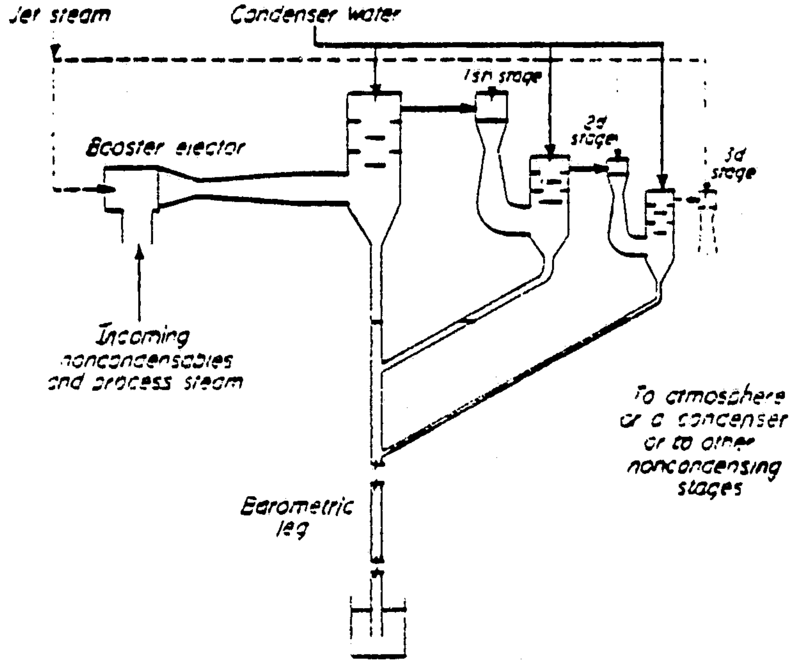
7.2.1 Petroleum Refining Processes

Vacuum Distillation

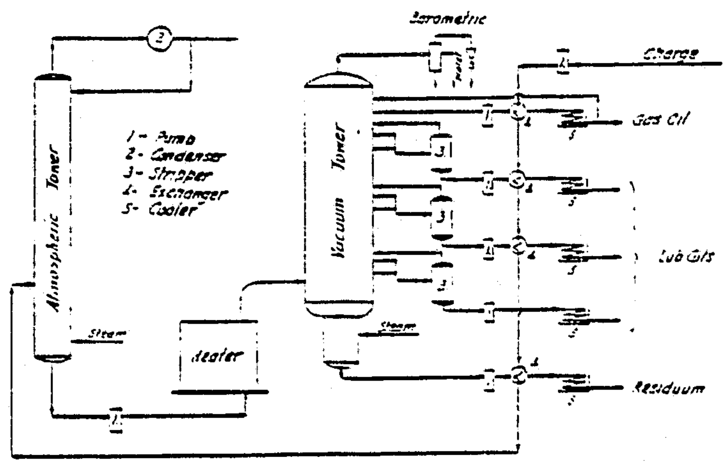
For the production of heavy gas oil, lubricating oil and bitumen fractions reduced oil from the atmospheric distillation column is heated in a direct-fired heater and then charged to a vacuum column. The flash temperature will typically be 390-400 C at 120mm Hg absolute. The partial pressure of the hydrocarbons is further reduced by the injection of steam. The steam added to the column, primarily for the stripping of bitumen in the base of the column, may amount to 15 pounds per barrel of feed and is normally superheated in a convection section in the feed heater.

Using standard trays, the vacuum distillation column may be very large -- diameters up to 45 feet. A low pressure drop across the trays is essential and the liquid seal must be minimal. Trays used in vacuum applications exhibit a much lower efficiency than trays used in atmospheric columns. As a result, most vacuum towers now use proprietary grid packings.

Multistage steam ejectors are normally used for vacuum development in conjunction with a barometric leg/direct contact condenser. An example of a common steam jet ejector system for vacuum tower operation is shown below:



Vacuum distillation is required for the removal of lighter fractions from the high boiling petroleum fractions since vigorous decomposition starts to take place at temperatures exceeding 710°F. Stocks in this category include reduced or topped crude, tars and heavy crudes. Some may require both steam and vacuum. A typical vacuum distillation system is shown below:



Heat for the atmospheric flashing is recovered by primary heat exchangers, while any additional heat required is available by introducing a small amount of reduced crude from the process heater outlet into the primary flash tower.

Vacuum distillation may be employed for the redistillation of pressure distillate, processes distillate, or bright stock solution. Vacuum systems are widely used to produce for catalytic cracking plant feed stocks.

Vacuum distillation is advantageous for producing lubricants from topped crude oils because the asphalt in asphaltic base stocks can make the cost of acid treatment prohibitive while in paraffin base oils the advantage lies in the larger recovery of valuable heavy stocks.

Because of the high boiler points of lubricating oil stocks, the use of vacuum alone is seldom sufficient. Process steam must also be used in quantities such as 1 pound steam for each gallon of reduced crude oil processed.

The pressure drop that occurs between the barometric condenser and the vaporizer section of the tower is of great importance. The purpose of vacuum operation is to produce low effective pressure at the vaporizer and hence the vacuum must not be lost by excessive friction through the vapor line, condensers, and tower plates.

TOTAL STEAM REQUIRED APPROX. IN VACUUM DISTILLATION FOR 1,000 BARRELS PER DAY TOPPED CRUDE

Pressure mm Hg produced by the vacuum system	750	200	100	60	50	40	35	30	25
Temp. at vaporizer, if no process steam is used, °F	950	830	780	750	735	725	715	708	700
Process steam, lb. for:									
Vaporizer at 720°F	10,300	2,490	1,070	460	325	190	122	54	
Vaporizer at 680°F	24,000	6,220	3,020	1,300	1,340	1,049	385	733	580
Jet steam, lb. for:									
80°F cooling water		150	232	378	492	830	1,600		
70°F cooling water		146	222	312	368	480	500	837	2,010
Total steam required, lb:									
680°F—80°F water	24,000	6,370	3,252	2,178	1,832	1,970	2,485		
680°F—70°F water	24,000	6,366	3,342	2,112	1,708	1,520	1,485	1,590	2,590
720°F—80°F water	10,300	2,640	1,302	838	847	1,020	1,722		
720°F—70°F water	10,300	2,636	1,292	772	693	670	722	911	2,010

In addition, a pressure drop of about 10 mm to the vaporizer for the lower pressures, and a larger pressure drop at higher pressures.

Vacuum distillation avoids undue cracking of products and is used where crude oil is to be reduced to a small percentage of bottoms. The overhead products include gas oils and heavy lubricating fractions, while the residuum is a viscous pitch used for fuel oil blending or coking.

The Annual Refining survey of the Oil and Gas Journal, March 20, 1978, shows that vacuum distillation is the largest proportional process contributor (next to crude oil distillation) in the U.S. with a 1977 cumulative charge capacity of over 6.3 MMB/sd.

Typical energy requirements in a vacuum distillation process in terms of energy utilized per barrel reduced crude charged, are: 40 lb. steam, 60,000 Btu of fuel, 0.5 kWh, and 800 gallons of cooling water. Yield patterns will vary widely but an average might be approximately 13% LVGO, 48% HVGO and 39% vacuum residual. The Oil and Gas Journal survey reported that the average refiner charge to vacuum distillation is 20,800 BPD using 2.55×10^9 BTU/day.

Thermal Cracking

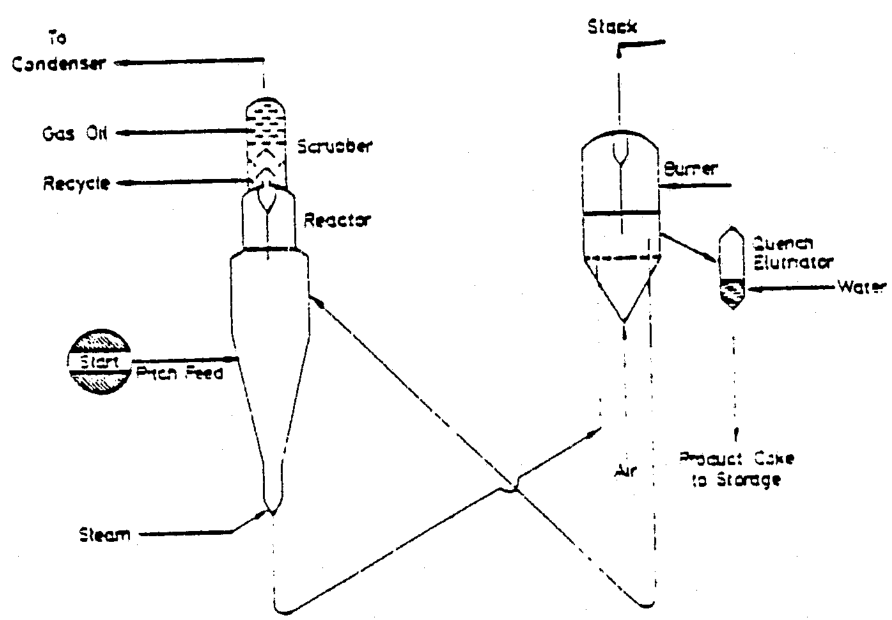
Thermal cracking is decreasing in usage because of the relative inflexibility of product slate. Modifications to refineries are eliminating this process. Thermal cracking is defined as the thermal decomposition, under pressure, of large hydrocarbon molecules to form smaller molecules. By using this technique, lighter and more valuable hydrocarbons may be obtained from low value stocks such as heavy gas oils and residuum. The largest use of the thermal cracking concept in the modern refinery is in steam cracking. Steam cracking is conducted at low pressures, high temperatures, low hydrocarbon partial pressures and in the vapor phase. This process is used to produce light olefins (ethylene, propylene, butenes, and butadienes). Other thermal cracking processes, such as visbreaking and coking, can be used to convert residues to lighter, higher value stocks.

Thermal cracking is normally conducted at temperatures varying from 455^oC to 730^oC and at pressures from 0-1000 psig. The important reactions include breaking the carbon-carbon bond, dehydrogenation, isomerization and polymerization. The first reaction turns out to be the most important. Irreversible endothermic cracking of paraffinic molecules or side chains yields lower-molecular-weight molecules, usually a paraffinic and an olefinic hydrocarbon.

Feed is introduced to the fractionator where it is heated. The lighter fractions are removed in a side stream, while the fractionator bottoms including a heavy product recycle are directed to the furnace. Outlet temperatures from the furnace vary from 480°C to 515°C. This heated oil enters one of the coking drums where cracking continues. The cracked products are drawn off the top of the drum, while coke forms on the inner surface of the drum. To provide for continuous operation, two coking drums are used -- while one is on-line the other is being cleaned. Temperatures in the coke drum range from 415°C to 450°C at pressures from 15 to 19 psig.

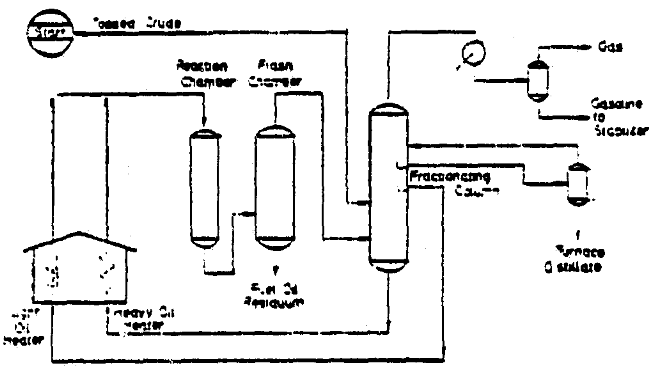
Overhead products return to the fractionator where the naphtha and heating oil fractions are taken off. The heavy recycle material is reheated with fresh feed. The coke drum is usually on stream for approximately 24 hours before becoming filled with porous coke. Twenty-four hours are normally required to clean the off-stream drum.

Fluid coking is a continuous process which uses a fluidized-solids technique to convert residuum to more valuable products. The use of the fluidized bed permits the coking reactions to be conducted at higher temperatures and shorter contact times than can be used in delayed coking. Because of this, less coke is generated resulting in higher yields of more valuable products. The process is shown below:



The rate at which hydrocarbons crack is strongly dependent on temperature, with cracking reactions beginning about 315°C - 370°C. Aromatics are the least crackable hydrocarbon class.

The majority of regular thermal cracking processes use temperatures of 455°C - 540°C and pressures of 10-1000 psig. The Dubbs process is the oldest process application and is charged with a wide boiling reduced crude. The intermediate boiling range products above gasoline are recycled to the heating coils, and the heavy residual tars or coke are rejected. The Dubbs process is shown in the schematic below:



The reduced crude feed is preheated by direct exchange with the cracked products in the fraction ating column. Cracked gasoline and heating oil are removed from the upper section of the column. Light and heavy distillate fractions are removed from the lower section and are pumped to separate heaters. Higher temperatures are used to crack the more refractory light distillate fraction.

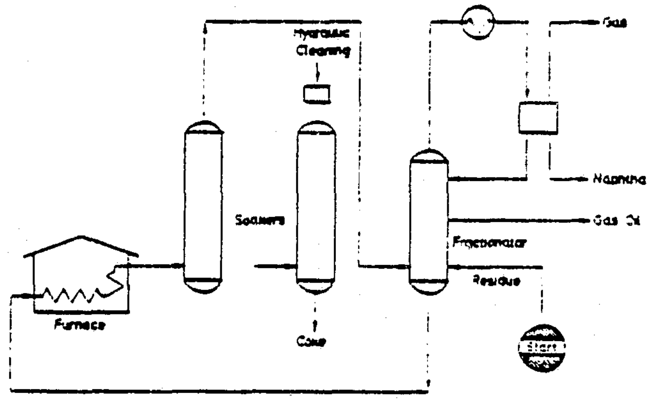
Time and temperature are the two factors which will influence cracking yields and product quality the most. The total yield of light products (gasoline, naphtha, kerosene) at a given temperature and pressure is a function of time, and achieves a maximum at a certain temperature.

Average energy requirements for thermal cracking per barrel of charge are: 122 lbs. steam, 700,000 BTU fuel, 2 kWh, and 2,000 gallons of cooling water. With a charge of 20-30^0 API gas oil, nominal yield patterns are 6% fuel gas, 2% propylene, 7% propane, 4% butylenes, 1% isobutane, 1% butane, 40% gasoline components, and 47% heavy fuel oil components. The <u>Oil and Gas Journal</u> survey reported the average refinery charging 1,500 bbl/day to the thermal cracker utilizing 1.34×10^9 BTU/day.

Coking

Coking processes are severe cracking operations designed to completely convert residual products (pitch and tar) into gas, naphtha, heating oil, gas oil and coke. The gas oil fraction represents the major product obtained and is further used as a major feedstock to catalytic cracking units. The coke obtained is normally used as a fule, but with some additional treatment, it is marketed for some specialty uses. Coking is becoming more lucrative because of the concentration of feedstock sulfur in the coke and the yield of products which can be readily desulfurized by coking. Two major coking processes are in use today, delayed and fluid coking.

Delayed coking is a semi-continuous process in which the heated charge (in this case residual product) is transferred to large soaking/coking drums which provide the long residence time needed to allow the severe cracking reactions to proceed. A sketch of the process is shown below:



Two vessels are used in fluid coking -- a reactor (coker) and a burner. The reactor holds a bed of fluidized coke particles with steam injected at the bottom to assist in the fluidization.

The residual feed enters the reactor at 260°C - 370°C. Coker vessel temperature ranges from 480°C - 565°C thus partially vaporizing and partially depositing incoming feed on fluidized coke particles. Heat is supplied by the circulating coke particles. The hot residuum on the coke particle cracks and vaporizes leaving the bed. The process leaves a residue which dries to form coke.

Average bed temperature in the burner is 590°C - 650°C, with air added as necessary to maintain the temperature by burning part of the coke. Pressures range from 5 - 25 psig.

Solids inventory is maintained by periodically withdrawing coke from the burner through the quench elutriation drum. Water is added to cool the coke, which is then sent to storage.

Recently, a combination of fluid coking and coke gasification has been developed whereby about 98% of the original crude oil residuum can be converted to lighter products.

Energy requirements for delayed coking per barrel charges are 38 lb. steam, 208,000 BTU fuel, 1.44 kWh and 1,300 gal. of cooling water. Charging 5 - 25° API residual results in approximately 8% fuel gas, 1% propylene, 1% butylenes, 1% isobutane, 1% normal butane, 19% gasoline components, 63% gas oils and 16% coke.

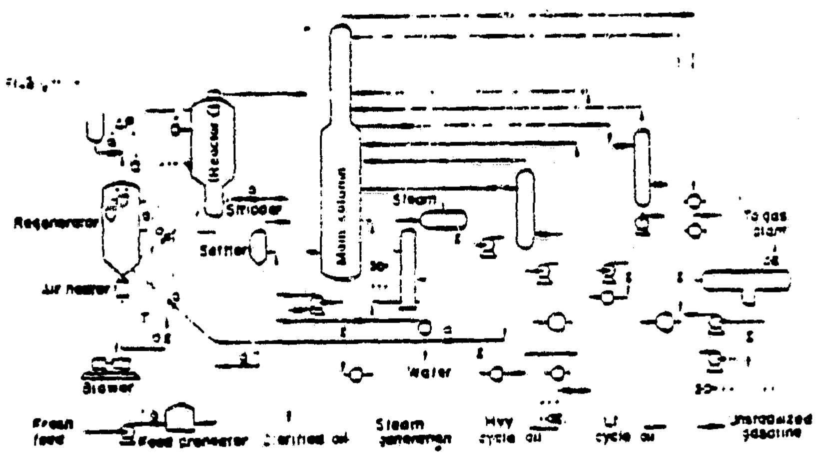
Catalytic Cracking

Catalytic cracking is the most important and widely used process for the production of gasoline components from heavy distillates.

Houdry discovered in 1927 that silica-alumina clays would catalyze the cracking of heavy fuels providing good yields of gasoline range petroleum fractions. The catalyst became quickly covered with carbon, however, and blocked active reaction sites thus reducing its cracking activity.

The catalytic capability could be restored by carefully burning off the carbon and thus effectively regenerating it for another cycle.

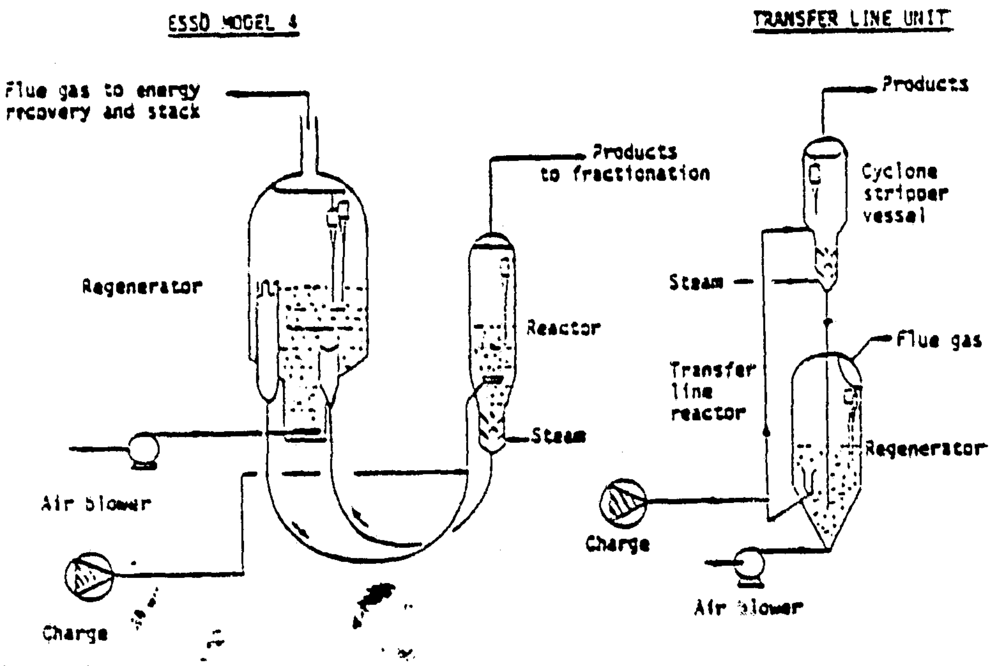
The fluid bed system will be discussed in detail since it represents the bulk of refinery applications. The catalyst used is normally a SiO_2/Al_2O_3 powder. A diagramatic representation of this process is shown below:



In the fluid process, preheated vaporized feed picks up hot regenerated catalyst, transports it in a dilute phase to the reactor where the vapor velocity is reduced and the catalyst settles into the steam stripper and thence flows to the regenerator. Coke is burned off with fluidizing air in the regeneration vessel, the regenerated catalyst then falling through the control valve to be picked up again by the feed.

The reactor effluent is directed to the main fractionating column where separation is made into gas, gasoline fractions, light and heavy gas oils, and residue. Two and three stage cyclonic collectors are used in both the reactor and the regenerator to remove entrained catalyst from exit vapors. Catalyst not removed by the cyclones remains in the regenerator is captured in electrostatic precipitators. Catalystic in the reactor product oil passed to a settler and the resulting slurry oil is pumped back to the reactor.

Catalyst flows are directed by properly adjusting differential pressures across control valves. Several generations of reactor/regenerator arrangements have improved performance and reduced vessel sizes. These include the pressure balance system, the transfer line unit, the Kellogg orthoflow unit and the Esso Model IV. Shown below are the Esso IV and the transfer line unit:



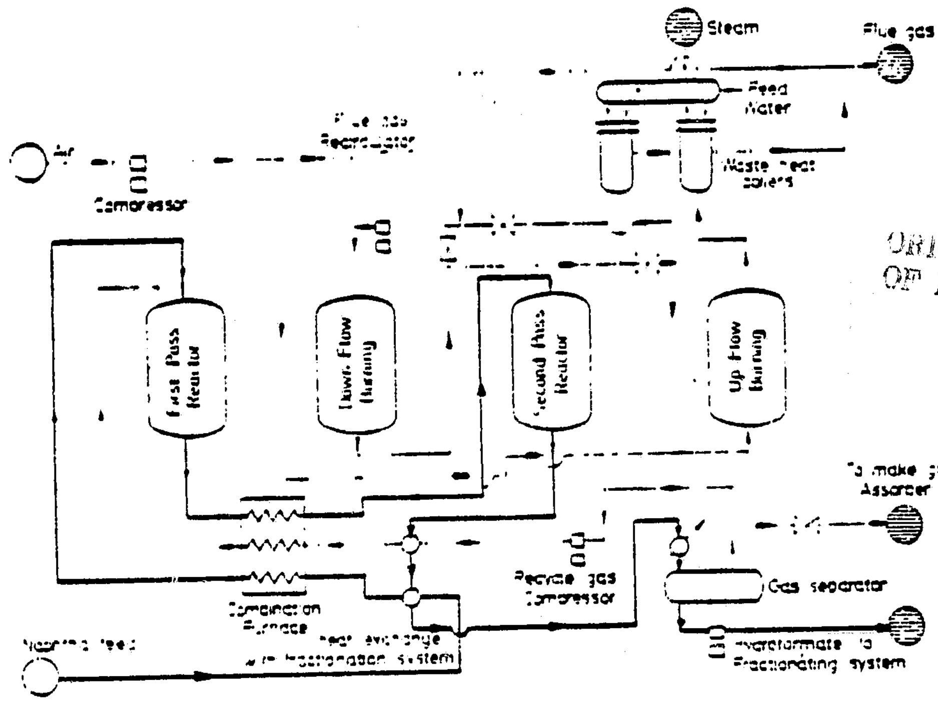
High yields of motor gasoline components with an octane number of 80 to 85 motor and 92 to 99 research are typically obtained. Product distribution can be varied somewhat to meet differing market requirements.

Energy utilized in fluidized catalytic cracking per barrel of charge results in a net export of 100 lb. steam, and a consumption of 105,000 BTU fuel, 2.50 kWh and 550 gallons of cooling water. Typical product distribution (charging LVGO-HVGO) is 2% fuel gas, 4% propylene, 2% propane, 5% butylenes, 5% isobutane, 1% normal butane, 52% gasoline components, 21% gas oil, and 14% heavy fuel oil components. Oil and gas Journal Survey Average Plant was determined to have a catalytic cracking charge rate of 18,269 barrels per day using 7 x 10^7 BTU/day.

Catalytic Reforming

Catalytic reforming is an efficient process for the production of high octane number hydrocarbons. The main feeds to the catalytic reformer are paraffins and naphthenes which undergo a number of reactions depending on the catalyst and the operating conditions. The major reactions are: dehydrogeneration, isomerization, dehydrocyclization, and hydrocracking.

The first catalytic reforming process was called hydroforming and was developed in 1939. A 9% by weight MoO_3-Alumina catalyst was used. However, under the high temperature, low hydrogen partial pressure conditions, coke was deposited on the catalyst, necessitating regeneration after 4-8 hours of processing. A simplified process drawing is shown here:



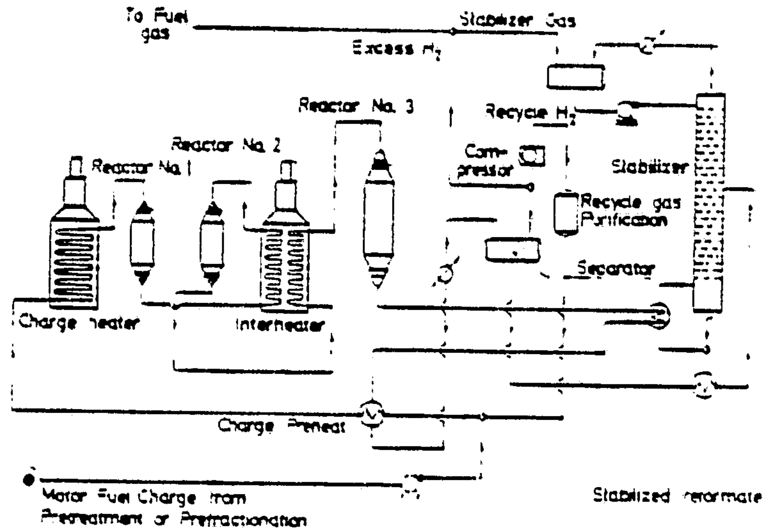
Two reactors are used for processing and two for regenerating. Feed and recycle are preheated to reaction temperature and passed to the first reactor. The highly endothermic reaction drops the temperature approximately 50°C and the reactants are reheated and passed to the second reactor. The products are then passed to a separator for cooling and for recycle of gases. In this separation process, accomplished by absorption/distillation, C_3, C_4, gasoline fractions, and hydrogen-rich excess gas are recovered. The MoO_3-Alumina acts as an effective desulfurization agent achieving about 90% sulfur removal. Conversion to aromatics is also very high. Hydroforming was widely used to produce toluene and xylene for aviation gasoline and explosives during WWII.

Two major catalytic reforming processes are being used today: processes designed to give long on-stream runs before catalyst regeneration and those in which the regeneration forms a portion of the processing cycle.

Long On-Stream Runs

Processes under this classification include UOP's Platforming, Sinclair Bake Reforming, Atlantic Refining's Catfining, and Houdry's Houdriforming. Process conditions normally used are:

Process:	300-600 psig
Temperature:	450^oC-540^oC
Space Velocity:	1.5-3.0 v/v/h
Hydro/Hydrocarbon Mol. Ratio:	5:1 - 10:1



Desulfurized feed is heated first in a product heat exchanger and then by a fired heater. It is then forwarded to reactor one. Naphthene dehydrogenation takes place and rapidly drops reactor temperature requiring the interheater for products prior to entry into reactor two. Further dehydrogenation and dehydrocyclization take place again severely dropping process temperature requiring additional reheating before entrance into reactor three. Products are then directed to a separator. The gasoline fraction is then passed to a stabilizer where the C_4 components and lighter materials are recovered.

All variations of the reforming process have a small (initial?) reactor since naphthene dehydrogenation is such a rapid reaction with a high space velocity. In the final reactor, the paraffins are dehydrocyclized to aromatics or are isomerized or hydrocracked. These reactions are slow and occur with a low space velocity.

During catalyst life, deactivation slowly takes place, and it is necessary to increase inlet temperatures in order to maintain octane number at the desired level. The higher temperatures favor cracking and there is a progressive loss of gasoline yield until the reactor is shut down and regenerated.

Catalytic reforming with on-stream regeneration. Processes of this type include powerforming and ultraforming. The major difference encountered in this system is the lower pressure operation of approximately 200-350 psig. The use of the lower pressure has several advantages:

- Higher gasoline yield due to less hydrocracking.
- Higher aromatic production because of more favorable conditions for naphthene dehydrogenation and paraffin dehydrocyclization.
- Higher hydrogen yields.

The disadvantage of the system is that the catalyst quickly deactivates because of coke deposition. This makes frequent regeneration essential.

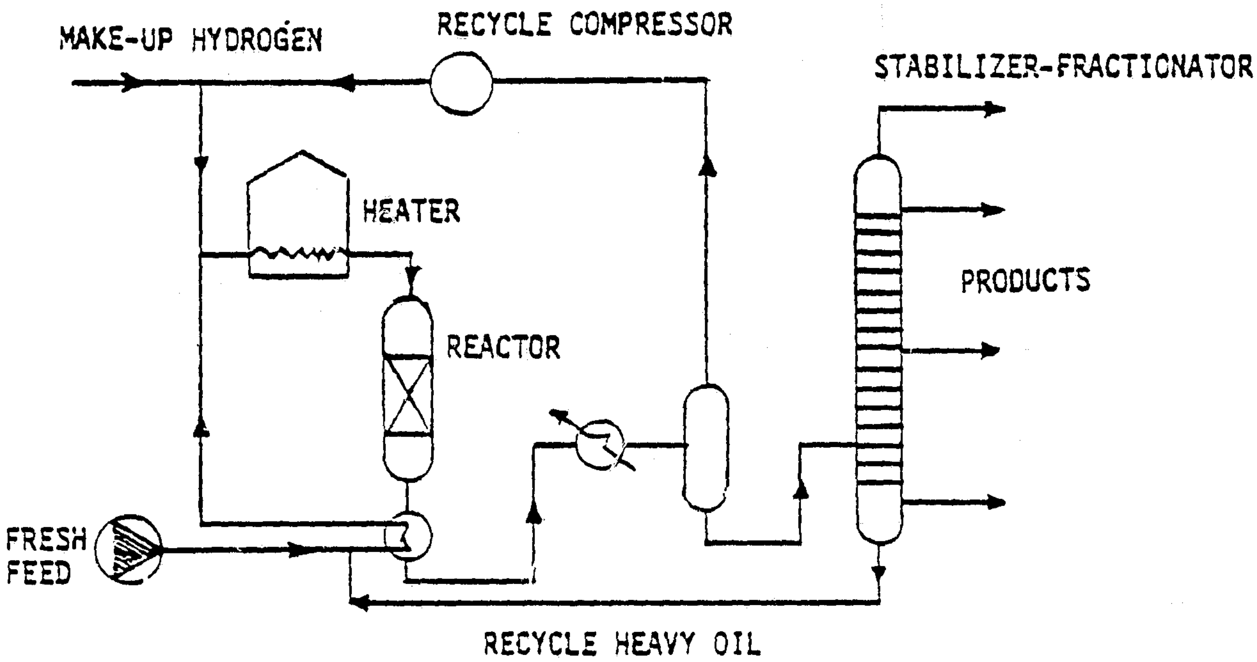
The process is used today primarily to upgrade low octane naphtha to high octane gasoline blending components containing large quantities of aromatic hydrocarbons. Charge stocks may be straight-run, hydro-cracked, hydrogenated thermo-cracked, and naphthas boiling in the range of C_6-400^oF. The charge may be full range naphtha or selected heart cuts.

Energy requirements for catalytic reforming per barrel charge are 380,000 BTU 3 kWh and 770 gallons of cooling water. No process steam is required.

Hydrocracking

Hydrocracking is used for the conversion of a wide range of hydrocarbon feedstocks to lighter products. Typical charge products are naphtha, light and heavy vacuum gas oils, desphalted residuum and topped crude. The refiner has a wide flexibility to produce different product slates emphasizing high octane gasoline blend stocks, jet fuel, low pour joint diesel, LPG, or low sulfur fuel oil blends.

The process normally employs a fixed bed catalyst system utilizing recycled hydrogen under an increased pressure. Product fractionation can be tailored to specific refinery needs. A typical single stage plant is shown below:



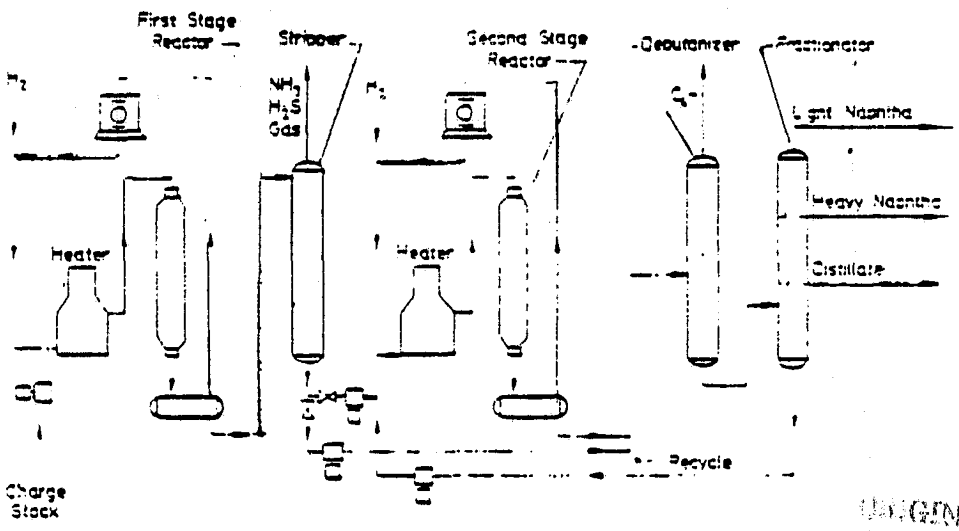
The mechanism of hydrocracking is similar to that of catalytic cracking with hydrogenation imposed. Carbonium ions are produced through olefin intermediates. The carbonium ion cracks. The resultant fragments are hydrogenated as a result of the high hydrogen partial pressure. This rapid hydrogenation prevents the olefinic molecules from absorbing on the catalyst.

One of the most important reactions is the partial hydrogenation of polycyclic aromatics followed by the splitting of the saturated rings to form substituted monocyclic aromatics. Over-hydrogenation can result in a loss of octane number and increased hydrogen absorption. Side chains of three or four carbon atoms are easily split off by catalytic cracking to yield isoparaffins and olefins.

Hydrocracking requires a dual-function catalyst with high cracking and hydrogenation potential. The catalyst base is normally provided by such materials as clays, zeolites-alumina or silica-alumina while the hydrogenation is supported by such materials as nickel, tungsten, platinum or palladium.

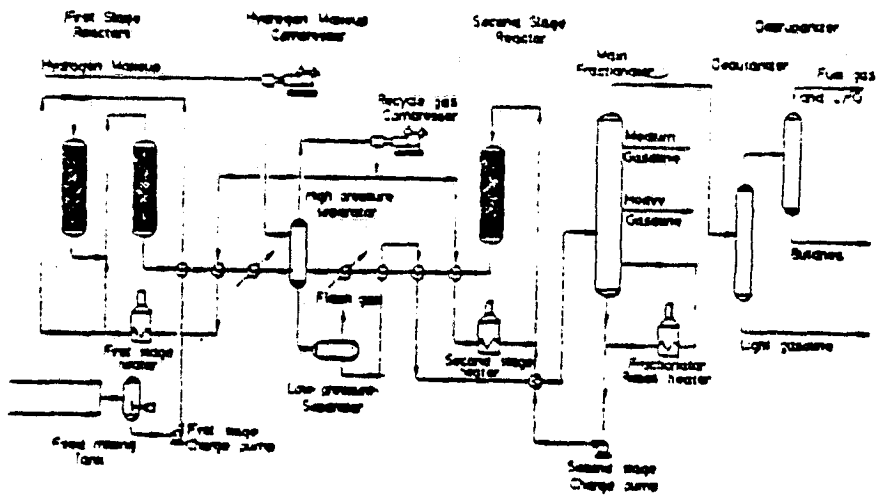
Among the processes currently being used, the most successful are Isomax (UOP and Chevron) and Unicracking-JHC (Union, Esso). Process conditions are typically:

Pressure:	1200-2000 psig
Space Velocity:	0.2-1.0 v/v/h
Hydrogen Recycle:	8000-15,000 scf/b
Temperature:	340°C - 420°C



The two stage Isomax system is shown above. Fresh charge stock and hydrogen are preheated and directed to the first stage reactor. Here the feed is desulfurized and denitrogenated. The resultant mixture is cooled, hydrogen gas is evolved and recycled. The liquid product is forwarded to a stripper where the light gases, H_2S, and ammonia are removed. The bottoms from the stripper are passed to the second reactor along with more hydrogen. In the second reactor the product is again hydrocracked, cooled, then debutanized and sent to the fractionator for separation of product.

A schematic layout of the Unicracking system is shown below:



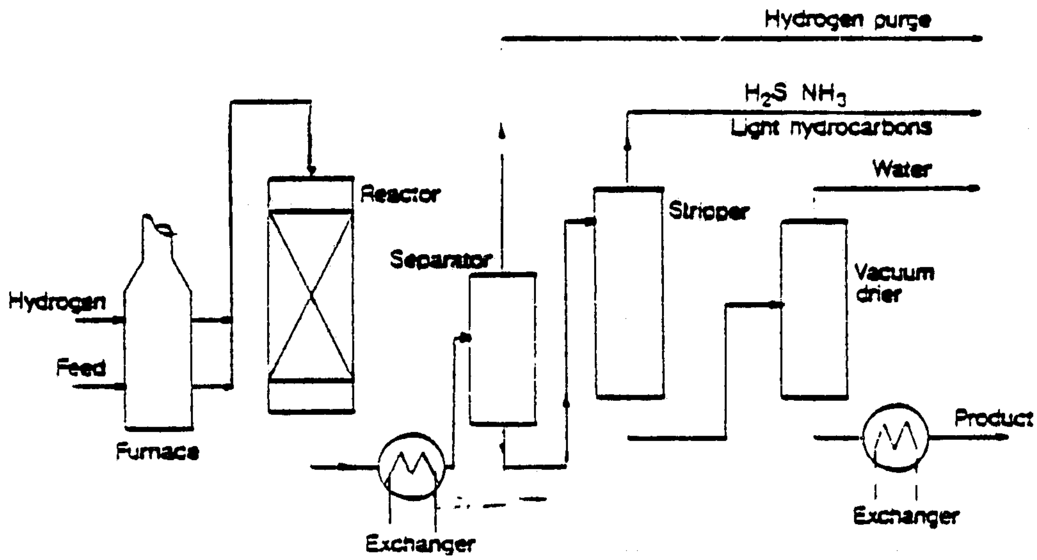
In the Unicracking system platinum or palladium is deposited on zeolite to provide the process catalyst. Feed and hydrogen are passed first to a hydroprocessing reactor and then to a hydrocracking reactor. The products are cooled, separated from the excess hydrogen and distilled. The unconverted bottoms are combined with additional hydrogen and recycled to the hydrocracking reactor.

Summarizing energy requirements for hydrocracking, each barrel charged to the process results in an export of 6 lbs. of steam and a consumption of 145,000 BTU of fuel, 8.20 kWh and 110 gallons of cooling water. Recalling that the process is extremely flexible, the product slate cannot be characterized because of specific refinery desires.

Hydrofining/Hydrotreating

Since hydrogen is often readily available from other refining process, it is widely used in the refining of lubricating oil products. Processes for the lube oil refinery have been classified as hydrofining, mild hydrotreating, and severe hydrotreating. Hydrofining is used to finish solvent-extracted base stocks, mild hydrotreating is used in solid lubricant manufacture, and severe hydrotreating produces high viscosity oils from raw petroleum feedstocks.

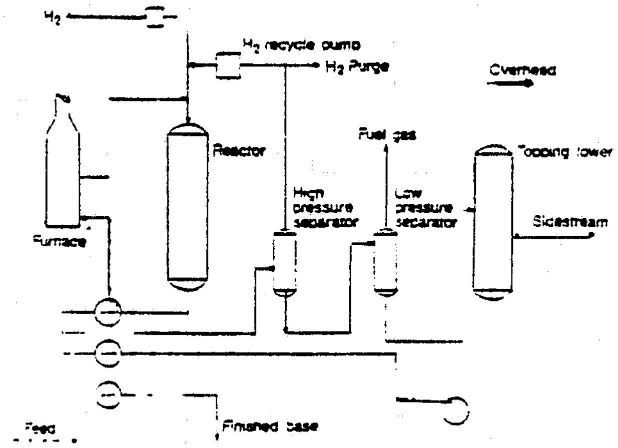
Hydrofining stabilizes undesirable oil components by mild catalytic hydrogenation. Oxygen compounds, sulfur and nitrogen are removed in the process. A rough schematic, shown below, depicts the process.



The feed and hydrogen are heated concurrently in the furnace and passed into a down-flow reactor. The product is cooled in the non-regenerative heat exchanger and is directed to the separator. In the separator, hydrogen and its reaction products (H_2S, NH_3, and light hydrocarbons) are disengaged from the main product. Steam stripping removes dissolved gases and traces of water are removed in the vacuum dryer.

Reactor temperatures range from 200°C - 420°C at pressures from 100-1200 psig. Space velocity can be as high as 2.0 v/hr/v. Again, a wide range of operating conditions are used, depending on product requirements and feedstock.

Mild hydrotreating can be used to produce naphthenic oils which are widely used as general industrial lubricants. It will also remove nitrogen compounds which can adversely effect product color and color stability. The process is shown here:



The mild hydrotreating process is similar to the hydrofining plant with the exception that a vacuum distillation column has been added for topping hydrotreated products.

The process is conducted at constant pressure and temperature. Temperatures range 260°C - 425°C with pressures up to 400 psig. The space velocity is varied to produce the desired level of product.

Severe hydrotreating is defined by the use of conditions which induce extensive hydrocracking in addition to the saturation of aromatics and the destructive hydrogenation of non-hydrocarbons. This hydrocracking process allows for high viscosity oil production without prior solvent extraction.

The process equipment is similar to that used for mild hydrotreating but must be designed for more demanding operating conditions. Oils from the severe process are dewaxed to meet pour point requirements. Severe hydrotreating can produce a wide range of high viscosity oils from low quality feeds. Base stocks are used in the formulation of multi-grade oils as well as high quality light lubricating oils, diesel fuel, and gasoline by-products.

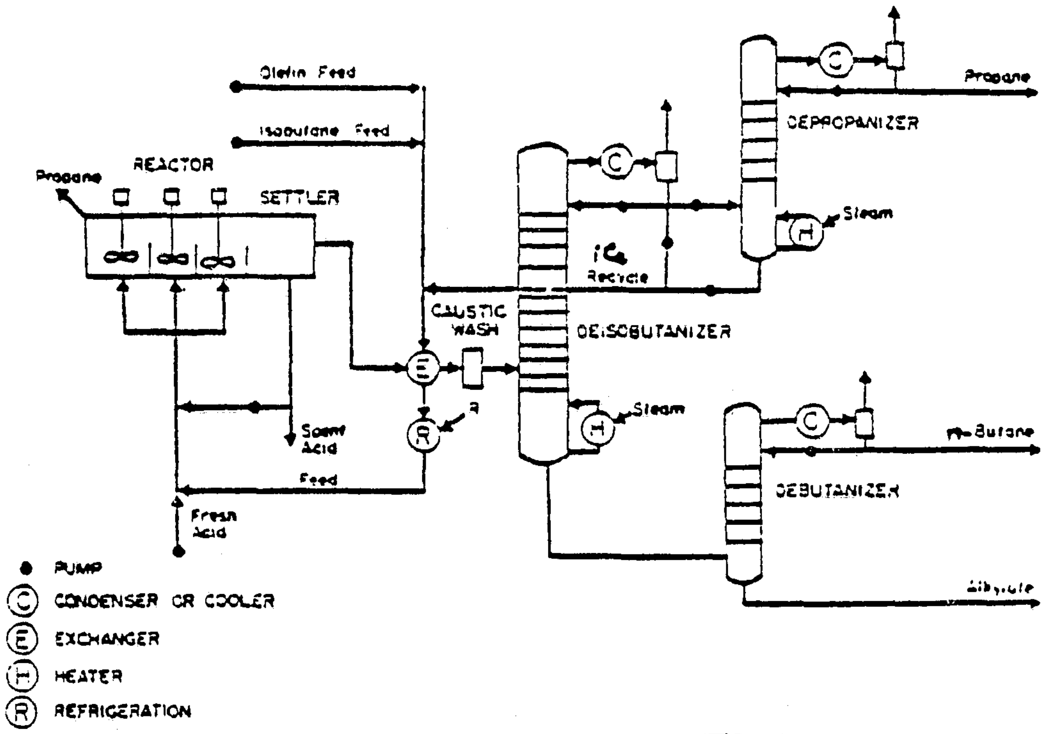
Naphtha hydrotreating nominally requires the following energy requirements per barrel of charge: 11 lb. steam, 53,000 BTU fuel, 1 kWh and 150 gallons of cooling water. Gas oil hydrotreating requires 25 lb. steam, 66,000 BTU fuel, 1.70 kWh, and 260 gallons of cooling water per barrel of charge.

Alkylation

Alkylation refers to a process in the petroleum industry for the production of high octane motor oil by the combination of olefins and paraffins. I. Impatieff discovered the reaction of isobutane with olefins using an aluminum chloride catalyst witn hydrogen chloride. Most commercial installations, however, alkylate isobutane with olefins using sulfuric acid or hydrogen fluoride as catalysts.

The process of sulfuric acid alkylation (probably, the most widely used) combined propylene, butylenes and amylenes with isobutane in the presence of strong sulfuric acid to produce high octane branched chain hydrocarbons for use in aviation gasoline and motor fuels.

Most of the new plants installed operate on a mixture of propylene and butylene. The total debutanized alkylate has an F-1 octane number of 92-96 (unleaded). Processing straight butylenes can produce an alkylate with F-1 octane numbers as high as 99.0 (unleaded). Endpoints of the mixed feeds are typically between 170°C - 200°C.



The feed streams (olefins and isobutanes) are combined with sulfuric acid (fresh plus recycle) and are charged to the stirred, contact reactor. The reactor contents are circulated at high velocities with the exposure of an extremely large interfacial area between reacting hydrocarbons and the catalyst. The reactor is maintained at a constant temperature. Since the reactions are exothermic, the heat of reaction is normally removed by propane refrigeration or by auto-refrigeration (allows some vaporization in the contactor).

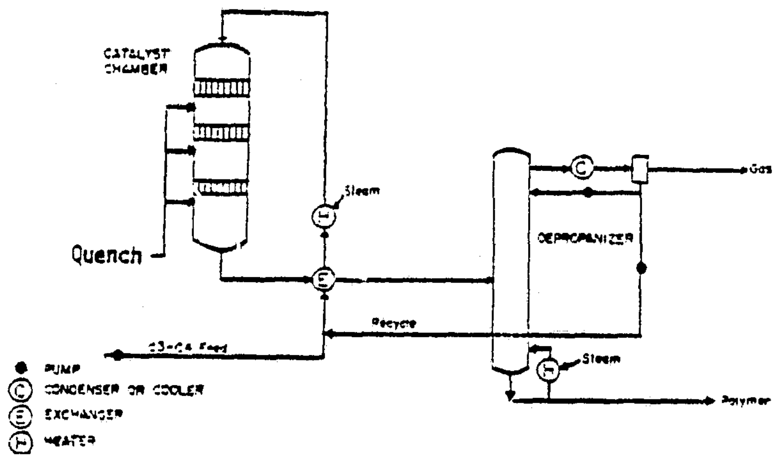
The most common designs currently in use are the Kellog cascade auto-refrigerated reactors and the Stratco effluent refrigeration alkylator.

Per barrel of olefin feed charged to the process, butylene alkylation nominally requires 477 pounds of steam, 249,000 BTU of fuel, 4.08 kWh and 4,985 gallons of cooling water.

Polymerization

Polymerization is used to produce a high octane gasoline blending component from olefins, typically propylene and butylene. Sulfuric or phosphoric acid may be used as the catalyst, with the latter being the most common.

Polymerization combines unsaturated materials to yield a product having a higher molecular weight than the feed. Thus, a hydrocarbon like propylene can be polymerized to a material boiling in the gasoline range. Feedstocks are normally available because refinery processes used in the industry to increase the quantity of high-quality gasoline also produce large quantities of gaseous material containing olefins. Thus, the process becomes one which is subsidiary, whose function is to produce a small increase in quantity of the total gasoline product at the expense of other refinery fuel gases.



A simplified flow diagram of the system is shown above. The catalyst is shown arranged in beds in the reactor. The reaction is exothermic and a quench is introduced between the catalyst beds. Quench oil is often a mixed propane that has passed through the reactor and is depleted in propylene.

The reactor is maintained at approximately 200°C at pressures from 500-1000 psig. Conversions of around 90% are obtained. Polymer gasoline F-1 clean octane number is about 98. If a predominantly C_3-C_4 charge is polymerized, the recovery section can be modified to yield a propane stream for liquified petroleum gas (LPG) sale as well as butene by the use of a depropanizer and a debutanizer. The type of feed that can be used varies widely. In non-selective polymerization in chamber plants, a C_3-C_4 olefin content of 20-25% is normal. When the olefin content in the feed rises above 25%, spent gas of low olefin content must be recycled with fresh feed. Smaller installations use the chamber type plant while larger installations use the tabular (exchange type) reactor.

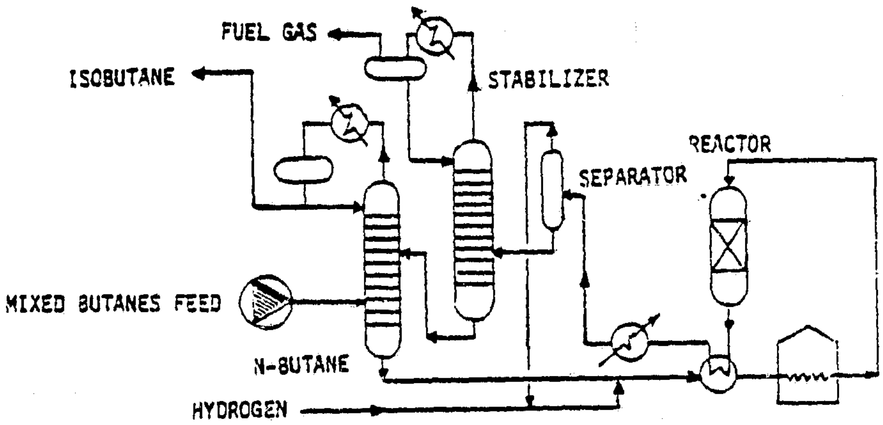
The liquid phosphoric acid process has been modified by California Research Corporation. The feed may be any type of olefin feedstock with olefin concentrations as high as 95%. The feed is caustic and water washed to remove sulfur and nitrogen compounds. The hydrocarbon feed and the liquid phosphoric acid are brought into intimate contact in a high efficiency reactor. The reactor effluent is separated into acid and hydrocarbon in a conventional settler and acid returned through a cooler. The product stream goes to recovery to yield polymer gasoline of the desired vapor pressure.

Propylene polymerization energy requirements per barrel of feed are 311 lb. steam, 2.64 kWh, and 980 gallons of cooling water. No fuel is required in the process. Butylene polymerization requires 270 lb. steam, 2.27 kWh, and 840 gallons of cooling water. Again, no fuel is required in the process.

Isomerization

Isomerization in petroleum refining serves two major purposes. First, it is used in converting n-butane into isobutane which can be alkylated to liquid hydrocarbons and thence into gasoline boiling range components. Secondly, it can be used to increase the octane number of a gasoline stock by converting n-paraffins into isoparaffins.

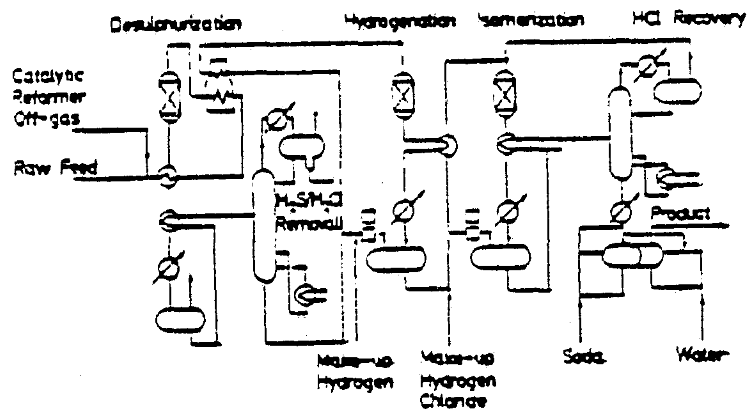
Basically, the isomerization of paraffins and naphthenes is a reversible first-order reaction limited by thermodynamic equilibrium. The reaction is exothermic and does not occur without a catalyst. The process is to contact hydrocarbons and the catalyst under favorable thermodynamic conditions. Aluminum chloride has been used as a catalyst, but most applications use a platinum containing catalyst. The most common isomerization processes are those for the isomerization of n-butane. The additional isobutane is needed for an alkylation feed because alkylation frequently consumes more isobutane than normally occurs in refinery streams.



A typical unit is shown in the flow diagram above. Mixed butane feed is charged to a deisobutanizer concentrating the normal butane in the bottom product. Next, the butane is mixed with hydrogen, heated and charged at moderate pressure to the reactor containing the special catalyst. The reactor effluent is cooled, whereupon hydrogen and light gases are separated from the liquid for recycling. The liquid component is stabilized in a conventional column. The stabilized bottom product is deisobutanized and high purity isobutane is taken overhead as a product along with any isobutane which was introduced in the fresh feed.

Butane isomerization operating conditions are 200-300 psig. Operating at this temperature UOP's Butamer process provide a 96% molar yield and volumetric yield of 100.3%. C5/C6 isoparaffins provide excellent highoctane components in the lower end of the gasoline range.

The diagram below shows the flow plan for a low temperature C5/C6 process system. Operating conditions are a pressure of 250-260 psig, temperature less than 160^{o}C, a single pass space velocity of 1.0-2.0 v/v/hr and a hydrogen: hydrogen not ratio of 2:1.



Feed is first purified by removing sulfur and water by catalytic desulfurization and distilled drying. The dry feed is also hydrogenated to saturate the olefins and benzene.

Essentially, no hydrogen consuming reactions take place in the isomerization process so hydrogen consumption is negligible. A small amount of hydrogen chloride is used in the recycle gas to help maintain catalyst activity, but since it is recovered in a distillation process, losses are small. The product can be blended without need for stabilization or rerunning.

Butane isomerization energy requirements per barrel of charge are 65 lb steam, 1.48 kWh, and 1,440 gallons of cooling water. No fuel input is required. Pentane/hexane isomerization requirements per barrel charge are 180,000 BTU fuel, 2.40 kWh, and 750 gallons of cooling water. No process steam is required.

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Hydrogen Production

The hydrogen requirements of modern large refineries are normally so large that a hydrogen production plant becomes a necessary part of the complex. Two main processes are used to produce this hydrogen, steam reforming and partial oxidation.

The methane/steam reforming reaction has been used for many years in the production of hydrogen.

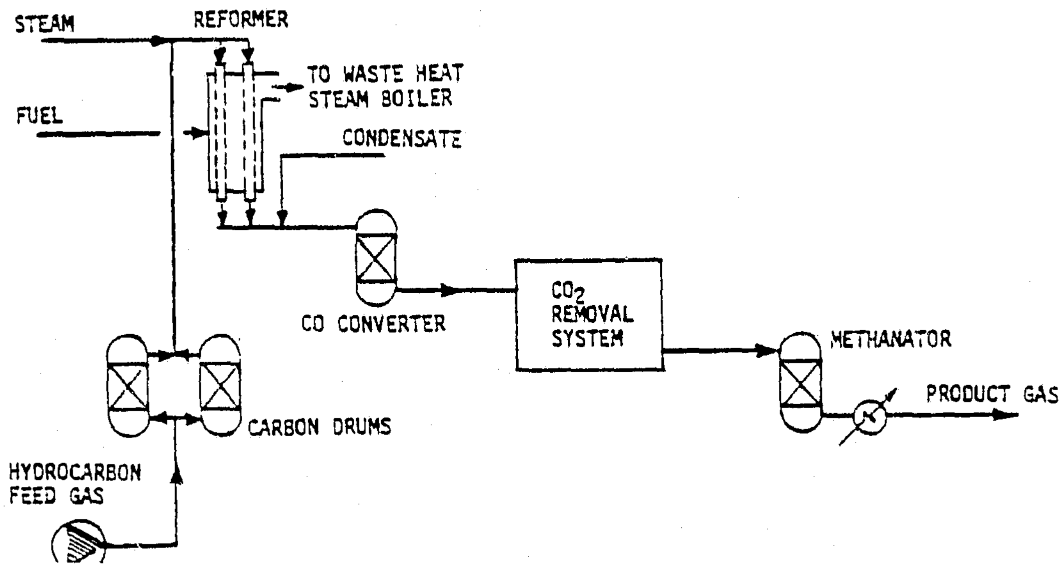
$$CH_4 + H_2O \longrightarrow CO + 3H_2$$

$$CO + H_2O \longrightarrow CO_2 + H_2$$

or extending to other hydrocarbons

$$C_nH_m + nH_2O \longrightarrow nCO + (n + m/2)H_2$$

Since the reaction results in a volume increase it naturally favors low pressures. However, since hydrogen is ultimately needed at high pressures, there is also an incentive to operate the process at as high a pressure as possible. A simplified flow diagram is shown below:



Steam reforming of light hydrocarbons is used for producing high purity hydrogen such as is needed for hydrogenation and hydrodesulfurization. Natural gas, refinery gas, propane, butane and naphtha are typical charge-stocks. The steam-hydrocarbon reforming process includes the basic steps of desulfurization, reforming, conversion, CO_2 removal and methanation.

Since sulfur poisons the catalysts used, the feed stock is passed through activated carbon to remove the sulfur compounds normally found in natural gas. Other desulfurization steps may be necessary for refinery gas or for heavier hydrocarbons. Superheated steam is added and the mixture flows into the reformer furnace, where reactions yielding hydrogen and carbon monoxide take place in the presence of a nickel catalyst at approximately 1400^{o}F to 1600^{o}F. Downstream "finishing" of the hydrogen included conversion of CO to the CO_2 by reaction with water vapor (producing more hydrogen), removal of the CO_2 and, finally, conversion of residual CO to methane by reaction with hydrogen.

An alternative method of hydrogen production is by partial combustion. In this process, the heat required to arrive at process conditions is supplied by combustion using a portion of the feed. The process is non-catalytic and can operate on any hydrocarbon feed from gas to fuel oil. Sulfur need not be removed since it is converted into H_2S and SO_2 which is easily removed from the product. Normal operating pressures are 30-40 atmospheres although a Texaco process reportedly operates at 80 atmospheres.

Partial oxidation has the advantage of being able to operate on low priced fuel oils with no restriction on the sulfur concentration.

Energy requirements for hydrogen production using the steam reforming process are 275,000 BTU fuel, 0.4 kWh, and 650 gallons of cooling water per equivalent barrel of light hydrocarbon feedstock.

CTAS Plant Data Sheet

A. Plant Name/Size: Small Refinery / 50-75 x 10^3 bbl/day

B. Products:

Product	lb/yr, etc.
Gasoline (motor, aviation)	1,185,900 b/cd
Distillates (fuel, kerosene, LP)	799,195 b/cd
Residuals (heavy oils, asphalts)	592,950 b/cd

C. Plant Kilowatt Requirements: Average 14,000 kW; Peak ________ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
8.33×10^4	@	400-600		
2.92×10^5	@	100-200		
	@			

E. Other Heat to Process (Describe):

Direct fuel to process heaters (natural gas and still gas, and oil)
2.1×10^{10} Btu/day

F. Plant Hours of Operation at Average Conditions: 8760 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Cat cracker air blower	10,000				Elecric or steam turbine
Alky refrig comp					"
Alky driver on contacter					"
Hydrotreating comp					

H. Operational Considerations:

The refinery consists of many tightly integrated processes which do not operate independently. Production and process conditions are uniformly controlled to maintain smooth operation.

I. Waste Heat Streams:

lb/hr	Temp.	Description
241,060	950 F	Catalytic cracker
30,875	970 F	Catalytic reformer
14,875	800 F	Hydrotreater

CTAS Plant Data Sheet

Plant Name/Size: Small Refinery / 50-75 x 10^3 bbl/day

J. Fuels: Primary Fuel crude oil derivatives / 4.75×10^5 mil. Btu/hr (HHV)

Secondary Fuel natural gas / 2.78×10^5 mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

Crude oil is not burned per se, but many components of the crude (heavy oil, coke, still gas, etc.) do constitute the primary fuel. Process steam allows flexibility and does not need to be produced only by the primary fuel.

L. Applications:

No. of Equivalent Plants in Years 1985-2000	Where	Cogeneration Potential
41-48 *		Yes

M. Application Discussion:

*Majority of growth expected to take place at existing locations -- process improvements in efficiency, etc. Petroleum industry growth assumed to be 2% per year from now to 1985, 1% per year thereafter.

N. Preferred Economic Criteria: Sophisticated, complex analysis based on refinery by refinery basis.

O. Economic Discussion:

The refinery business is highly capital intensive. Maximum run time is obtained from equipment.

P. Duty Cycle and Maintenance Philosophy:

Continuous run philosophy. Major maintenance is performed by individual processes on an annual or biannual basis.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

NA

CTAS Plant Data Sheet

Plant Name/Size: Small Refinery / 50-75 x 10^3 bbl/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Industry wide - $37.5 billion (about $10 billion in small refineries)

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 3,033,000 b/cd

In 2000 4,064,400 b/cd

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 0.56 Q

In 1985 0.58 Q

In 2000 0.63 Q

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Plants are going to get bigger. Smaller refineries are expected to grow by about 35%.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See Process Description.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

9% Based on crude oil disappearance and purchased fuels in refinery processing.

Small Refinery / 50-75 x 10^3 bbl/day

U. Increasing amount of waste heat recovery, reductions in the purchased fuels (natural gas) and a substitution of coal with efficient burner management. Lube oils will probably be replaced by synthetic oils.

V. Increased imports. The contribution of shale oils will be evident, secondary and tertiary recovery methods will be practiced. Price structure will be drastically changed.

CTAS Plant Data Sheet

A. Plant Name/Size: Medium Refinery / 150 x 10^3 bbl/day

B. Products:

Product	lb/yr, etc.
Gasoline	1,933,750 b/cd
Distillates	1,121,575 b/cd
Residuals	812,175 b/cd

C. Plant Kilowatt Requirements: Average 52,000 kW; Peak ________ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
3.75×10^5	@	400-600		
9.58×10^5	@	100-200		
	@			

E. Other Heat to Process (Describe):
Direct fuel consumption (natural gas & still gas, fuel oil)
7.5×10^{10} Btu/day

F. Plant Hours of Operation at Average Conditions: 8760 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Cat cracker air blower					Electric or Steam
Alky refrig comp					Turbine
Alky driver on contactor					"
Hydrotreating comp					"
Coking air blower					"
Forced draft cooling					

H. Operational Considerations:

The refinery consists of many tightly integrated processes which do not operate independently. Production and process conditions are uniformly controlled to maintain smooth operation.

I. Waste Heat Streams:

lb/hr	Temp.	Description
70,300	1200 F	Fluid coking
494,800	950 F	Catalytic cracker
81,250	970 F	Catalytic reformer
46,375	800 F	Hydrotreater

CTAS Plant Data Sheet

Plant Name/Size: Medium Refinery / 150 x 10^3 bbl/day

J. Fuels:

Primary Fuel	crude oil derivatives /	7.18×10^5	mil. Btu/hr (HHV)
Secondary Fuel	natural gas /	4.22×10^5	mil. Btu/hr (HHV)
By-product Fuel	/		mil. Btu/hr (HHV)

K. Fuels Discussion:

Crude oil is not burned per se, but many components of the crude (heavy oil, coke, still gas, etc.) do constitute the primary fuel. Process steam allows flexibility and does not need to be produced only by the primary fuel.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
40-47 *	Near existing locations	yes

M. Application Discussion:

*Majority of growth expected to take place at existing locations -- process improvements in efficiency, etc. Petroleum industry growth assumed to be 2% per year from now to 1985, 1% per year thereafter.

N. Preferred Economic Criteria: Sophisticated, complex analysis based on refinery by refinery basis.

O. Economic Discussion:

The refinery business is highly capital intensive. Maximum run time is obtained from equipment.

P. Duty Cycle and Maintenance Philosophy:

Continuous run philosophy. Major maintenance is performed by individual processes on an annual or biannual basis.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

N/A

CTAS Plant Data Sheet

Plant Name/Size: Medium Refinery / 150 x 10^3 bbl/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Industry wide - $37.5 billion (about $12.5 billion in medium refineries)

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 4,550,000 b/cd

In 2000 6,096,600 b/cd

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 0.85 Q

In 1985 0.87 Q

In 2000 0.95 Q

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Plants are going to get bigger. Smaller refineries and medium sized plants expected to grow approximately 35% by 2000.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See process description.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

9%

Medium Refinery / 150 x 10^3 bbl/day

U. Increasing amounts of waste heat recovery, reductions in purchased fuels (natural gas), and a substitution of coal with efficient burner management. Lube oils will probably be replaced by synthetic oils.

V. Increased imports. The contribution of shale oils will be evident, secondary and tertiary recovery methods will be practiced. Price structure will be drastically modified.

CTAS Plant Data Sheet

A. Plant Name/Size: Large Refinery / 350 x 10^3 bbl/day

B. Products:

Product	lb/yr, etc.
Gasoline	2,792,250 b/cd
Distillates	1,619,500 b/cd
Residuals	1,172,750 b/cd

C. Plant Kilowatt Requirements: Average 126,000 kW; Peak ______ kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
5.42×10^5	@	400-600		
2.5×10^6	@	100-200		
	@			

E. Other Heat to Process (Describe):

Direct fuel consumption (natural gas and still gas, fuel oil)
1.63×10^{11} Btu/day

F. Plant Hours of Operation at Average Conditions: 8760 hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Cat cracker air blower					Electric or Steam Turbine
Alky refrig compressor					
Alky driver on contactor					"
Hydrocracker ~~compressor~~					
Hydrotreating compressor					"
Coking air blower					"
Forced draft cooling tower					

H. Operational Considerations:

The refinery consists of many tightly integrated processes which do not operate independently. Production and process conditions are uniformly controlled to maintain smooth operation.

I. Waste Heat Streams:

lb/hr	Temp.	Description
98,437	1200 F	Fluid coking
888,125	950 F	Catalytic cracker
182,000	970 F	Catalytic reformer
43,750	950 F	Hydrocracker
73,500	800 F	Hydrotreater

CTAS Plant Data Sheet

Plant Name/Size: Large Refinery / 350×10^3 bbl/day

J. Fuels:

Primary Fuel	Crude Oil Derivatives /	1.03×10^6	mil. Btu/hr (HHV)
Secondary Fuel	Natural Gas /	6.07×10^5	mil. Btu/hr (HHV)
By-product Fuel	/		mil. Btu/hr (HHV)

K. Fuels Discussion:

Crude oil is not burned per se, but many components of the crude (heavy oil, coke, still gas, etc.) do constitute the primary fuel. Process steam allows flexibility and does not need to be produced only by the primary fuel.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
20-22 *		Yes

M. Application Discussion:

*Majority of growth expected to take place at existing locations -- process improvements in efficiency, etc. Petroleum industry growth assumed to be 2% per year from now to 1985, 1% thereafter.

N. Preferred Economic Criteria: Sophisticated, complex analysis based on refinery by refinery basis

O. Economic Discussion:

The refinery business is highly capital intensive. Maximum run time is obtained from equipment.

P. Duty Cycle and Maintenance Philosophy:

Continuous run philosophy. Major maintenance is performed by individual processes on an annual or biannual basis.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

N/A

CTAS Plant Data Sheet

Plant Name/Size: Large Refinery / 350 x 10^3 bbl/day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Industry wide -- $37.5 Billion (about $15 billion in large refineries)

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

T. What is the national capacity for producing this product

Now in 1978 6,570,000 b/cd

In 2000 8,806,200 b/cd

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

--see attachment--

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

--see attachment--

W. National energy consumed by this process

In 1978 1.22 Q

In 1985 1.25 Q

In 2000 1.28 Q

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Plants will get much bigger. Large refineries should be expected to grow ~25%.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy.

See process description.

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

9%

Large Refinery / 350 x 10^3 bbl/day

U. Increasing amounts of waste heat recovery, reductions in the purchased fuels (natural gas) and a substitution of coal with efficient burner management. Lube oils will probably be replaced by synthetic oils.

V. Increased imports. The contribution of shale oils will be evident, secondary and tertiary recovery methods will be practiced. Price structure will be drastically revised.

8.0 PORTLAND CEMENT

SIC NO. 3241

8.1 INTRODUCTION

This section for the Portland cement portion of the CTAS cogeneration study has been organized into three major subsections as follows:

8.2 Background
8.3 Existing Facilities
8.4 Trends
8.5 CTAS Model - Process and Plant Data

In general, this paper - progresses from the history and a discussion of the cement making process through present trends, and finally to a projection of the nature of plants to be installed between the present and the year 2000. The data presented for the CTAS model is either estimated, obtained from other publications or is from actual engineering data from Kaiser Engineers' job files for preheater/precalciner facilities.

8.2 BACKGROUND

Dr. R. L. Handy of Iowa State University reduced the cement making process to ultimate simplicity:

"Take two cups of crushed limestone, add one-half cup of clay or pulverized shale (plus perhaps some sandstone or iron ore, depending), mix thoroughly and grind up fine. Bake in a white-hot oven at about 2600° F. Cool. Add a tablespoon of gypsum and, again, grind very fine. If you can do this for about a penny a pound, you can almost compete."

The cement industry utilizes two basic processes, wet or dry. In the wet process, the crushed raw materials are ground with water to 80 minus 200 mesh, thoroughly mixed, and fed into the kiln in slurry form. Under the dry process the raw materials are similarly ground, air blended and then fed into the kiln. Although both processes produce cement of equal quality, the wet process, due to ease of blending and material handling, has until recently been dominant in the U.S.

Recent technological efforts have been aimed at improving fuel efficiency. As a result, two innovations -- the dry process air suspension preheaters and flash or pre-calciners, have been developed. Suspension preheaters are a product of European technology. The preheater suspends the raw mix in the hot exit gases of the kiln. Productivity and thermal efficiency are both improved since these gases drive off residual moisture and partially calcine the raw material before it enters the kiln.

Air suspension preheaters combined with precalciners offer further advantages. Developed by the Japanese, the process basically involves the addition of a furnace between the third and fourth stages of preheating. The furnace increases the amount of heat available for calcination in the preheater so that the feed entering the kiln is approximately 90% calcined. By providing heat at the point of calcination, the flash calciner reduces the

need for a larger kiln. In fact, kiln diameter may be reduced by as much as 50% with no loss in production capacity. Other reported advantges include longer brick life, better process control, low NO_2 and SO_2 emissions, the ability to use lower grade fuel and/or coal, and lower capital costs for large capacity units.

Another recent improvement is the development of the roller mill which combines the tertiary crushing, grinding and drying stages into one step thereby replacing ball mills, separators, bucket elevators, and other auxiliaries. This replacement not only reduces capital cost, but also increases thermal efficiency since it uses exit gases from the kiln preheaters to dry and air classify the raw material.

8.2.1 Reserves

Raw materials for the production of cement are abundant. Many domestic companies report reserves exceeding 100 years at present annual capacity, while others report 25 - 100 years.

8.3 EXISTING FACILIITES

8.3.1 Capital Investment

In 1974, the Portland Cement Association estimated that the capital cost of a new plant was equivalent to $70 per ton of capacity; it is estimated that the current cost of a new plant is about $100 per ton of capacity. The cost of converting plants from wet to dry process is also high, amounting to about $50 per ton of capacity.

The present domestic Portland cement production rate is estimated at approximately 84,800,000 tons per year. At a replacement value of approximately $100 per ton of annual capacity, this represents a total capital investment of $8.4 billion dollars.

8.3.2 Current Wet and Dry Plants

For years, domestic companies made cement by the wet process because of the availability of low cost fuel. Wet plants still account for approximately 50% of the total U.S. cement production -- the remaining 50% is produced by the dry process - either long dry kilns, suspension preheater kilns or precalciner kilns. Precalciner kilns are replacing both wet process kilns and long dry kilns.

8.3.3 Process Description

The manufacture of Portland cement basically consists of grinding and blending a mixture of shale and limestone; clinkering the mixture in a kiln; adding small amounts gypsum to the clinker and then grinding this mixture to produce bag or bulk cement.

For the purpose of this portion of the CTAS study, the process is described under the following areas and is applicable to either wet or dry process facilities.

- Quarrying
- Raw Materials Crushing
- Raw Materials Grinding
- Raw Materials Blending
- Burning
- Clinker Cooling
- Finish Grinding

Quarrying

Limestone and shale are ordinarily quarried close to the cement plant using conventional drilling and blasting techniques. (Ripping can be employed in some softer rock). The blasted rock is ordinarily recovered by shovel or front end loader and transported to a primary crusher located in or very close to the quarry. In a few locations, the shale and limestone may be of the correct proportions so that one quarry will suffice; however, separate shale and limestone quarries are most common.

Energy usage in the quarry is in the form of explosives and mobile equipment and, therefore, the quarry area does not lend itself to cogeneration.

Raw Materials Crushing

The quarried raw materials are crushed by one, two and possibly three stages of crushing. Various types of crushers can be used, including jaw, gyratory, roll, and impact crushers.

Raw Materials Grinding

Prior to the development of roller mills, grinding was performed either wet or dry in rod mill and/or ball mill circuits. The roller mill has become dominant because tertiary crushing, grinding and drying are combined into one unit which not only reduces capital cost, but also increases thermal efficiency since kiln preheater/ precalciner exit gas is used to dry and air classify the raw material.

Raw Materials Blending

Limestone and shale (and occasionally other additives) must be thoroughly blended prior to being fed into the kiln. Several blending techniques are possible including preblending (where the materials are mechanically blended before being fed into the roller mill) and air blending after the roller mill using fluidizing silos.

Burning

Approximately 90% of all energy used in a cement plant is used for burning in the kiln/precalciner. The preheater tower brings the rotary kiln off-gas

into intimate contact with the raw material feed (raw mix) through four stages of cyclines. In the precalciner kiln, burners are installed between the third and fourth stage of the preheater tower in order to precalcine the raw mix before the raw mix enters the rotary kiln. Up to 60% of the total fuel may be consumed in the precalciner. A burner in the rotary kiln (consuming the remaining 40% of the fuel in this example) sinters the precalcined raw mix into clinker which is then discharged for cooling. In most preheater and precalciner installations, hot exhaust gas is then cooled in a spray tower before passing into a roller mill and this gas stream is a candidate for possible cogeneration.

Cooling

Ambient air is drawn through the clinker in order to air cool the clinker prior to the finish grinding step. The clinker cooler hot air is then drawn into the kiln/precalciner for combustion air. A substantial portion of the hot clinker cooler air is not drawn into the kiln and is instead filtered and then wasted to atmosphere. This gas stream is a candidate for possible cogeneration.

Finish Grinding

After the clinker is cooled, small amounts (approximately 5%) of gypsum are added to the clinker and the resulting mix is dry ground in a ball mill(s) (also called finish mills). Excessive heat in the grinding circuit will impair the quality of the finish cement and consequently a cement cooler is installed in the finish mill circuit. This cooler produces relatively small amounts of waste heat in the form of hot water and could be considered as a candidate for cogeneration.

8.3.4 Typical Plant Sizes - Existing Plants

A typical wet process kiln is capable of producing approximately 250,000 TPY of cement. One facility may produce from 200,000 TPY up to 2-million TPY of cement - an average size would be approximately 600,000 TPY for one plant.

A typical long dry kiln will produce approximately 300,000 TPY of cement. Suspension preheater and precalciner kilns in general have a larger production capacity than wet or long dry kilns - typically a preheater/precalciner kiln produces from 600,000 TPY up to a recent 1,400,000 TPY capacity for a single kiln.

8.3.5 Typical Energy Consumption Data - Existing Plants

Fuel Consumption

The Federal Energy Administration has indicated that the U.S. cement industry is one of the most energy intensive industries in the nation. In 1972, the industry averaged close to 7.0 million Btu's per ton of cement produced. Due to increased fuel prices and the elimination of some older, less efficient plants, energy usage has improved. In 1975, energy usage declined to 5.8 million Btu's/ton of cement produced.

Power Consumption

Power consumption has remained approximately constant in the United States between 150 KWH and 160 KWH per ton of cement. The dry process precalciner kilns consume approximately 10-15 KW/Ton of cement more than a wet process, however, the industry is gradually reducing overall power requirements.

8.4 TRENDS

8.4.1 Production - 1978 Base

Present demand for Portland Cement is approximately 84.8 million TPY. As of 1975, total capacity was 104 million TPY made up of 60.8 million TPY wet process capacity and 43.2 million TPY dry process capacity.

Since 1975, several wet process plants have been replaced with dry process facilities and we estimate the 1978 base production as 50 million TPY dry process capacity and 54 million TPY wet process capacity.

8.4.2 Production Increases 1978 - 1985

Projections by the U.S. Bureau of Mines, The Portland Cement Association and Cembureau indicate that demand will grow at a rate of about 3% in the U.S. and about 2.5% in the rest-of-the world through 1985. By 1985, therefore, demand for cement will amount to about 130 million TPY in the U.S. Assuming 10 million tons of imports and a 90% utilization rate, domestic capacity requirements will amount to approximately 133 million TPY vs. an estimated current capacity of 104 million TPY. Thus, an additional 29 million tons of new capacity will have to be added by 1985.

In addition, assuming that one-third of wet process plants will be closed, 19 million TPY of capacity will require conversion from wet to dry process.

8.4.3 Production Increases 1985 - 2000

Assuming that domestic production continues to grow at a rate of 2% per year between 1985 and 2000, an additional 46 million TPY of new capacit will have to be added for a total capacity of approximately 179 million TP

In addition, we believe that the remaining wet plants will be phased out of production so that an additional 35 million TPY of capacity will require conversion from wet to dry process.

8.4.4 Energy Requirements 1978, 1985 and 2000

The following table shows the approximate energy requirements during this time period:

	Total Annual Production-Tons	Average BTU/Ton	Average KWH/Ton
1978	104,000,000	5,600,000	160
1985	133,000,000	4,800,000	155
2000	179,000,000	3,500,000	150

8.4.5 Environmental Control - Impact on Energy Consumption

As with other industries, cement plants are faced with increasingly strict environmental controls. Fortunately, cement dust is not-toxic and pollution control equipment consists primarily of dry collectors to remove particulates from both process and fugitive emission pickup gas streams. Large dust collectors or electrostatic precipitators are used to remove particulates from the main kiln exhaust gas stream. Smaller dust collectors are used to recover particulates from fugitive emission points such as conveyor transfer points, chutes or other dust sources.

SO_2 emissions are generally very low since the majority of any SO_2 in the gas stream, (including SO_2 resulting from the sulfur content of oil or coal) reacts with the raw materials and reports to the finish cement product.

Given the fact that SO_2 emission levels are very low and the fact that NO_x emissions are presently being reduced by precalciners, it appears that the only foreseeable environmental control that may influence cement plant energy consumption would be a stricter standard for particulates.

8.4.6 Coal Firing

Coal firing is not new to the cement industry, however, until recently, the availability of relatively inexpensive oil and natural gas has resulted in limited use of coal. This trend has been reversed and virtually all new facilities will be coal fired with oil and natural gas used for startup and standby emergency firing only. (All of the projects currently underway in KE's engineering division will utilize coal firing.) The cement process can in many instances utilize hi-sulfur content coal without adversely affecting the finish cement. In fact, the ash resulting from coal firing is added to the clinker and slightly increases the total amount of clinker produced.

The disadvantage to coal firing lies primarily with expensive handling systems and with an increased danger of explosions over petroleum fuels. (Pulverized coal is very explosive and if allowed to remain in storage, as in a bin, it will self-ignite and explode.)

8.4.7 New Processes

The precalciner is relatively new to the cement industry and is the most modern commercially operating process. Other processes are under development, however, they are not commercially proven, therefore we do not foresee that they will be utilized on any large scale, if at all, between the present and the year 2000.

8.5 CTAS MODEL

While many wet and long dry kilns are still in existance, the trend is to replace these facilities and to build new facilities utilizing the new energy efficient precalciner kilns and roller mills. In our opinion, precalciner kilns will represent the large majority of replacement and new cement projects and, therefore, precalciner kilns and roller mills will be used for the CTAS Model.

Preheater kilns are also very energy efficient with approximately the same fuel consumption/ton of cement as precalciner kilns. Precalciner kilns are more popular and are most likely to be utilized over a preheater kiln because of the following observed advantages and reported advantages:

Observed Advantages

- o Operating availability is increased
- o Operating problems - specifically scaling in tower - are reduced
- o Lower grade fuels and junk fuels can be used

Reported Advantages

- o Less refractory consumption
- o Kiln specific volume is increased (220% more capacity for a given rotary kiln size vs. a similar preheater
- o More stable and controllable operation
- o NO_x emissions are lower
- o Capital Cost/Ton is lower for large capacity units

The basic precalciner kiln flowsheet is shown on Fig. 1 in this section. Several variations of the precalciner itself are possible - Fig. 2 shows nine commercial variations. A discussion of the streams and operating philosophy follows.

8.5.1 General

Quarry

As discussed earlier, energy usage in the quarry is in the form of mobile equipment and explosives and offers little potential for cogeneration.

Crushing

Large primary and secondary crushers are driven by large electric motors and offer no potential for cogeneration.

Grinding

As discussed earlier, the roller mill incorporates tertiary crushing, grinding, and drying into one piece of equipment and does not produce significant waste energy streams suitable for cogeneration.

Blending

Blending systems are basically dry process air-blending utilizing a fluidizing silo. Mechanical preblending (in which materials are stacked in layered beds for mechanical reclaim) is being used to supplement air-blending and results in a lower total power demand. Blending systems have little potential for cogeneration.

Kiln/Precalciner

The kiln/precalciner offers the most potential for cogeneration. The various possible off-gas streams are discussed under paragraph 8.5.6.

Clinker Cooler

The clinker cooler is intimately tied to the kiln operation and operates on the same schedule as the kiln. Clinker is cooled from approximately 2350° F to 150° F using ambient air. The heat given up by the clinker is approximately 880,000 BTU/ton.

The clinker cooler vent stream is a possible candidate for cogeneration and is discussed under paragraph 8.5.6.

Finish Milling

Finish mills are driven by large electric motors and only a small percent (5%) of the input energy goes into grinding the clinker finish cement. The remaining energy is required to turn the ball charge and ends up as heat. Since excess heat has an adverse effect on the finish cement, grinding temperatures are kept below 180° F by any combination of air sprays, ambient air and water cooled heat exchangers. Approximately 56,000 BTU/ton of cement is dissipated through air, water spray and/or cement coolers.

8.5.2 Operating Philosophy

While the kiln is designed to run continuously at a maximum capacity for 24 hr/day, 7 day/week, 330 day/yr; buffer storage piles and silos permit the remaining equipment to operate on a more flexible schedule. Thus the quarry (and crushing area which is usually tied to quarry operation) operate during daylight hours between five and seven days a week.

The roller mill is ordinarily sized for a slightly larger flowrate than the kiln and operates 80 - 90% of the time. The mill is shut down for maintenance and, during roller mill shutdowns, the kiln is run on stored material and the hot kiln off-gas is bypassed around the roller mill. In the future, roller mills may be oversized in order to utilize off-peak power rates. This is not presently economical as the increased capital cost for an oversize mill more than offsets the savings from grinding during off-peak hours.

Because the majority of energy input into the finish mill goes into turning the ball charge, there is no money to be saved from running the mill at reduced capacity and consequently the finish mill is run "flat-out" i.e. fed as much clinker as it can possibly handle.

Finish grinding is frequently scheduled to take advantage of off-peak hour power rates.

8.5.3 Typical Power Curve

To date, there is only one precalciner kiln in operation in the United States (although several are in various stages of design and construction) and because of the lack of operating data, we cannot accurately predict typical curves other than to say that when excess finish grinding capacity (finish mill) exists, that this operation will be scheduled to take advantage of off-peak hours at night.

The seasonal variations in power demand are generally more pronounced, particularly when the plant shuts down once or twice a year for approximately 30 days to rebrick the kiln and for general maintenance.

For a 1-million TPY facility built between the present and the year 2000, the power requirements are estimated as follows:

Peak Demand - 19,400 KW

8-5 Daytime Average (Excluding Downtime) - 16,500 KW

5-8 Nightime Average (Excluding Downtime) - 12,800 KW

Yearly Average - 13,000 KW

Large horsepower loads in a plant this size are as follows:

Item	Normal hp	Peak hp	Speed	Probable Driver
Roller Mill	2000	2500	900	AC Synchronous
I.D. Fans	4400	5500	1200	DC or AC Induction
Finish Mill	6350	6350	200-1200	AC Synchronous

8.5.4 Criticality of Power Failure

The rotary kiln is the one piece of process equipment that must continue to rotate in event of a power failure - if a hot kiln ceases to rotate, differential cooling may warp the kiln. Consequently, all cement kilns are provided with standby drives - either diesel, gas or electric motors powered by standby generators.

The remaining process equipment is less susceptible to damage during a power failure and the only other emergency power requirements would be for lighting, fire protection and personnel safety.

8.5.5 Typical Plant Size - 1978 to 2000

The present lower limit for precalciner kilns is approximately 500,000 TPY. The largest planned domestic precalciner kiln has a capacity of 1,400,000 TPY and, therefore, the projected range for upcoming conversions and new facilities is between 500,000 to 1,500,000 TPY per kiln with a 1,000,000 TPY selected as an average size for the CTAS model.

8.5.6 Process Data

For the purpose of the CTAS study, we have assumed that a 1,000,000 TPY precalciner kiln utilizing a roller mill will be typical of cement plants built between 1978 and 2000. The general flowsheet for such a plant is shown on Fig. 1. The following lists the assumptions, process stream data and our interpretation of the suitability of each stream for energy recovery.

8.5.6.1 Notes and References

The gas flowrates and temperatures shown on the CTAS plant model flowsheet were taken in part from design data for a 1,000,000 ton/yr coal fired precalciner kiln facility. This flowsheet is based on 0% alkali bypass, 6% moisture in the raw materials and a heat consumption of 3,000,000 BTU/Ton of cement. Other flowrates are approximate and are based on data from other systems.

8.5.6.2 Process Flowstream Data

Reference - Fig. I Flowsheet
The following is a list of typical data for the major streams in a 1,000,000 TPY precalciner kiln cement plant utilizing a roller mill for raw grinding. The stream numbers listed below refer to the stream numbers on the flowsheet.

Stream No.

1. Kiln off-gas.
   220,000 ACFM @ 200°F (Roller Mill Operating)
   304,000 ACFM @ 550°F (Roller Mill Being Bypassed)
   Dust loading minimal (Clean side of baghouse)

2. Dusty off-gas stream. Temperature is approximately 50°F higher than stream 1 above because of heat losses through insulated ductwork and baghouse.

3. 270,000 ACFM @ 700°F, dusty

4. 5100 Ton/Day Raw Material Feed

5. Secondary air duct (used for combustion air in precalciner). Note that in some systems (i.e. planetary coolers), all the clinker cooler exhaust gas is drawn through the rotary kiln and therefore, streams 5 and 8 are not present. In this example, stream 5 is assumed at 156,000 ACFM @ 1500°F, dusty

6. 102,000 ACFM @ 2270°F, dusty

7. Hot clinker. 2880 Ton/Day @ 2400°F

8. Cooler Vent. 335,000 ACFM @ 400°F, dusty

9. Cooler Vent. 300,000 ACFM @ 300°F, clean. (Note - baghouse and ducts are not insulated because there is no dewpoint problem-consequently cooler vent air cools approximately 100°F in the system ducts and baghouse.

10. Cool Clinker. 2880 Ton/Day @ 150°F

11. Portland Cement 3030 Ton/Day @ 180°F.

12. Hot Water 60 gpm @ 160°F

<u>Other</u>

This facility will consume approximately 3,000,000 BTU per ton of cement or approximately 380,000,000 BTUH using coal burners located at the rotary kiln and at the precalciner.

8.5.6.3 Possible Waste Heat Recovery Points

The following is a discussion of four points in the process flow from which waste heat may be recovered. This flowsheet has been simplified with the intent of illustrating possible applications for cogeneration systems. We are aware that a given plant could vary significantly from the model and that each plant would have to be studied in detail before a cogeneration system could be utilized.

<u>Waste Heat Recovery Point</u>

1. <u>Kiln off-gas</u>

   This stream has two conditions - 220,000 ACFM at 200° F for approximately 140 hours a week (roller mill operating) and 304,000 ACFM at 550° F for 28 hours a week (roller mill down). This location is logical since the stream is not dusty and potential dewpoint problems would not affect the baghouse - only the fan, ducts and stack which could be lined or corrosion resistant. Dewpoint problems could occur at approximately 150-200° F.

2. Precalciner off-gas

In some (but not all applications) there is excess heat in this stream over what is required to dry the raw materials. This stream is approximately 270,000 ACFM at 700° F and is cooled to approximately 400-600° F (dependent on the moisture in the raw materials). Assuming 500° F average, there are approximately 2,500,000 BTUH available for recovery at this point.

Other factors must be taken into consideration if this stream is used for cogeneration.

a) The stream is dusty (20-25 grains/ACF of limestone, shale and clinker dust).

b) Good temperature control is critical - in general, roller mill exit gas must not exceed 225° F, otherwise internal damage will occur to this very expensive equipment. General practice is to install one on-line and two standby water sprays in this tower. Failure of this spray is critical as the roller mill, ducts, I.D fan and baghouse would be destroyed.

c) The heat that can be extracted from this stream is not constant. Kiln and precalciner burners are adjusted during normal and upset conditions.

d) If an electrostatic precipitator is used for dust collection in lieu of a baghouse, the stream must be humidified for proper operation of the precipitator. This moisture can come from either the moisture in the raw material feed or from sprays in the cooling tower. In many instances the raw material is relatively wet and all the heat in this stream is needed to dry the raw materials. In this case a heat recovery unit could operate only when the roller mill is on bypass or approximately 28 hours a week.

e) A heat recovery unit must have a low air side pressure drop and be capable of being bypassed when not in use, otherwise, a high pressure drop at the large flowrate involved would increase the size of the I.D. fan, negating any power savings.

3. Cooler Vent

(Note that this stream does not exist in those plants that utilize a planetary clinker cooler.) The 300,000 ACFM @ 300° F air flow on the clean side of the baghouse lends itself to waste heat recovery/cogeneration systems. Further energy could be recovered by insulating all preceeding ductwork and the baghouse so that less heat is lost through radiation and conduction. Several companies are already utilizing or investigating the utilization of this stream for hot water heaters, oil heaters, etc.

This stream is relatively constant, being tied to kiln operation, but can experience upset conditions of up to 1000° F at the clinker cooler so that large amounts of tempering air are necessary to protect the baghouse. During an upset the flowrate could double to 600,000 ACFM with the temperature increasing to 500° F. Upsets may account for approximately 4% of the total operating time.

4. Hot Water

Some heat/energy could be recovered from the hot water exit from the cement cooler at approximately 60 gpm at 160° F. This stream would be tied to the finish mill operating schedule-operating approximately 140 hours a week during off-peak hours.

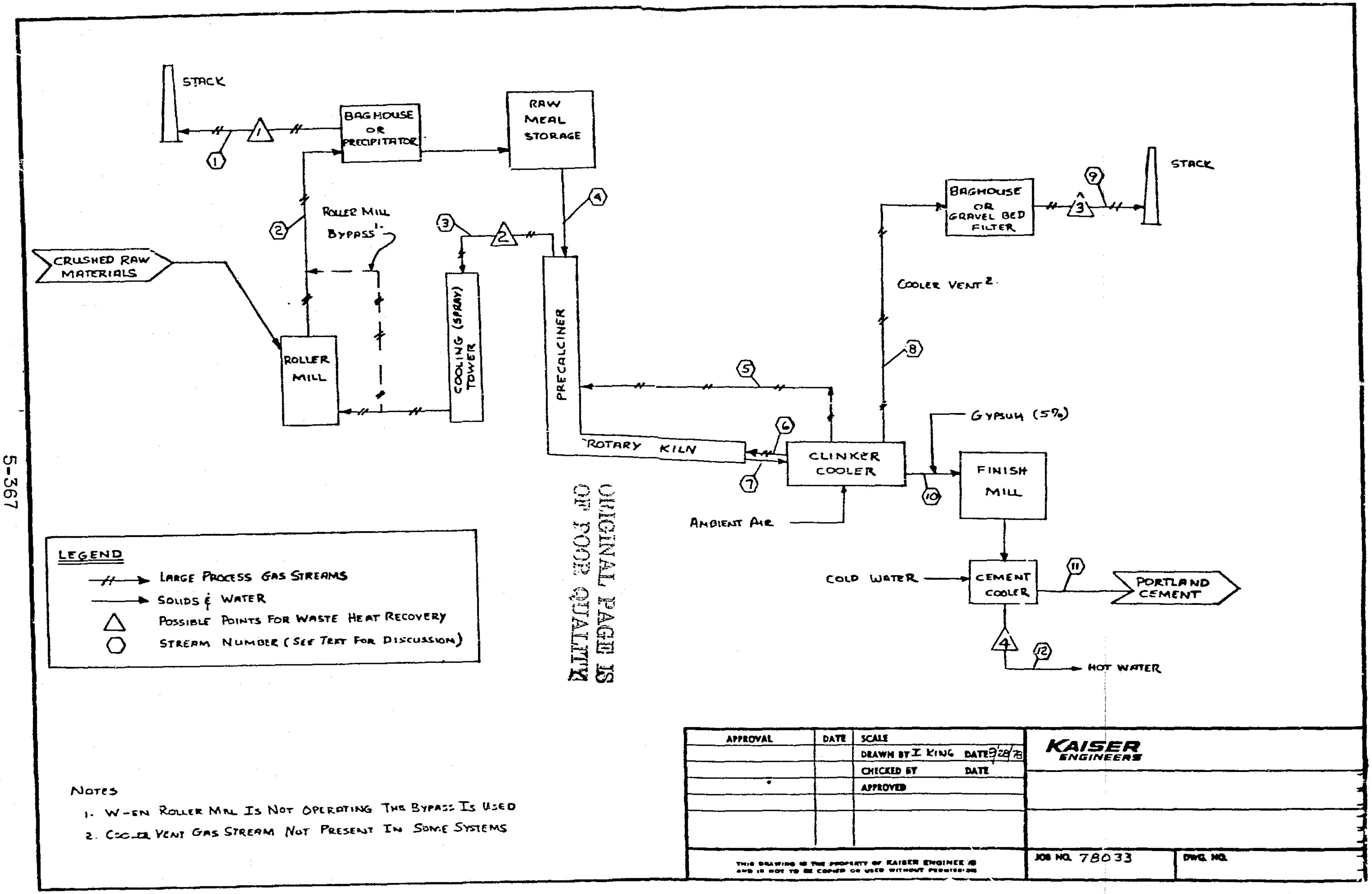


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Figure 1. - CMAS cement plant model.

C-5

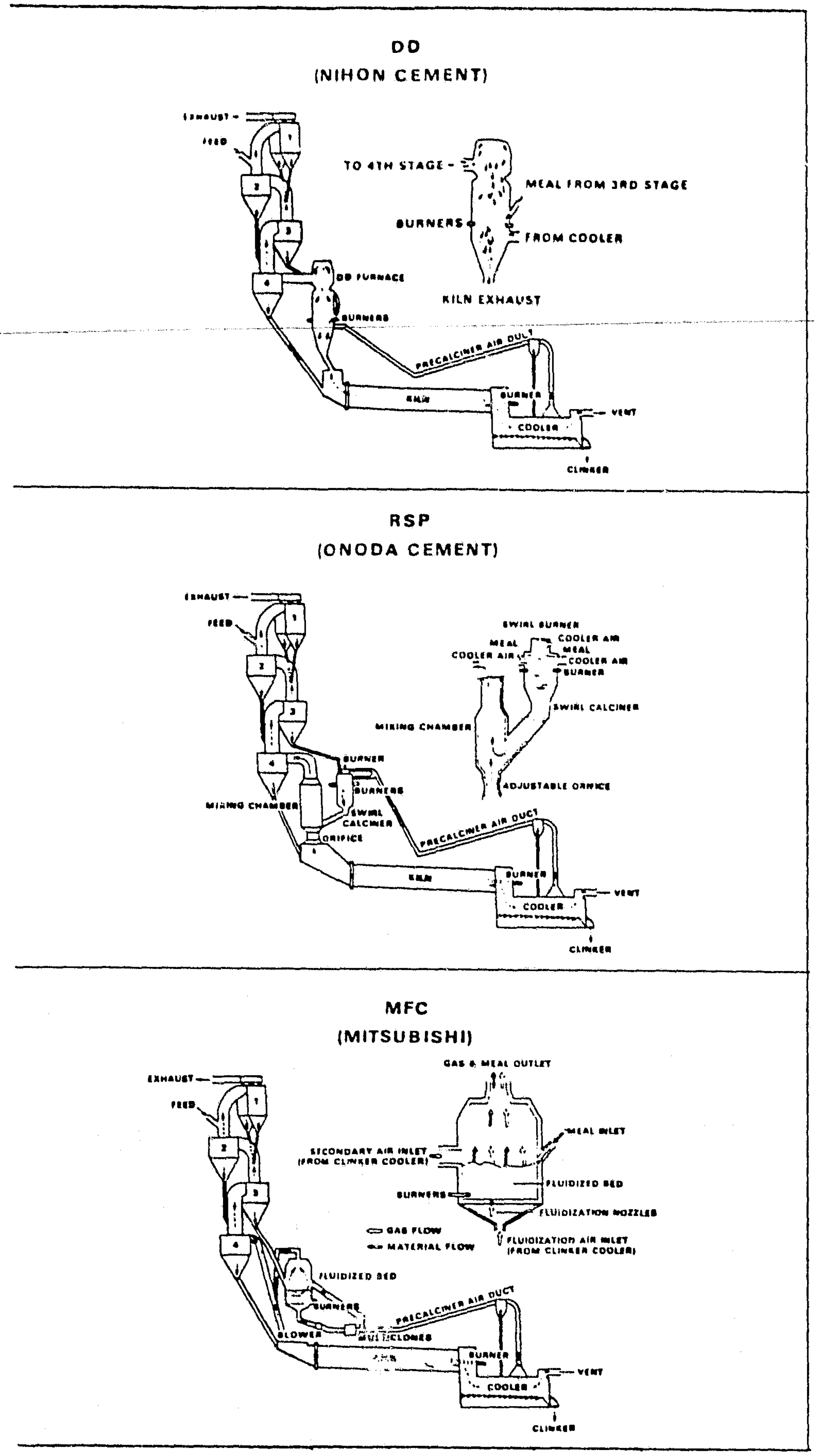


Figure 2. Precalciner Process

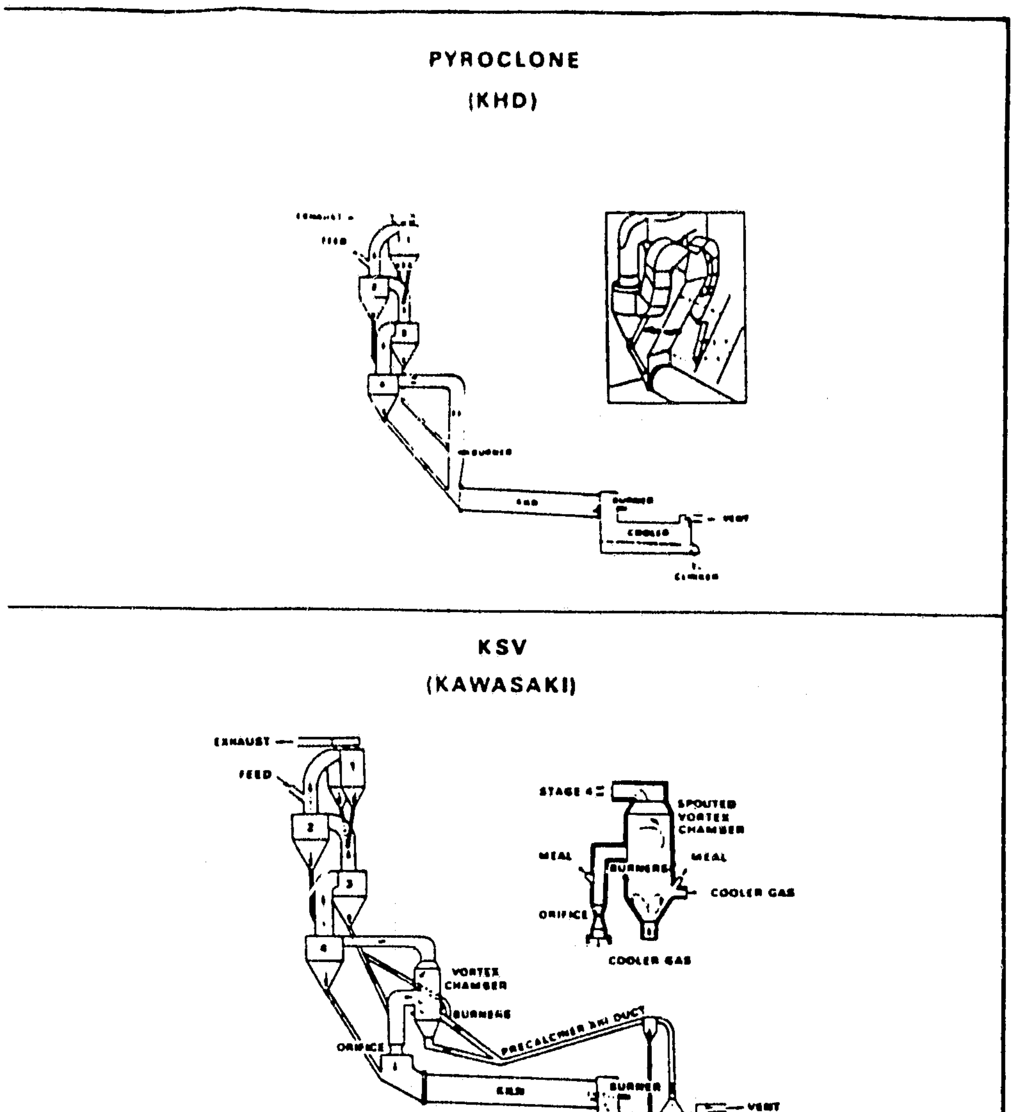


Figure 2 (Cont'd). Precalciner Process

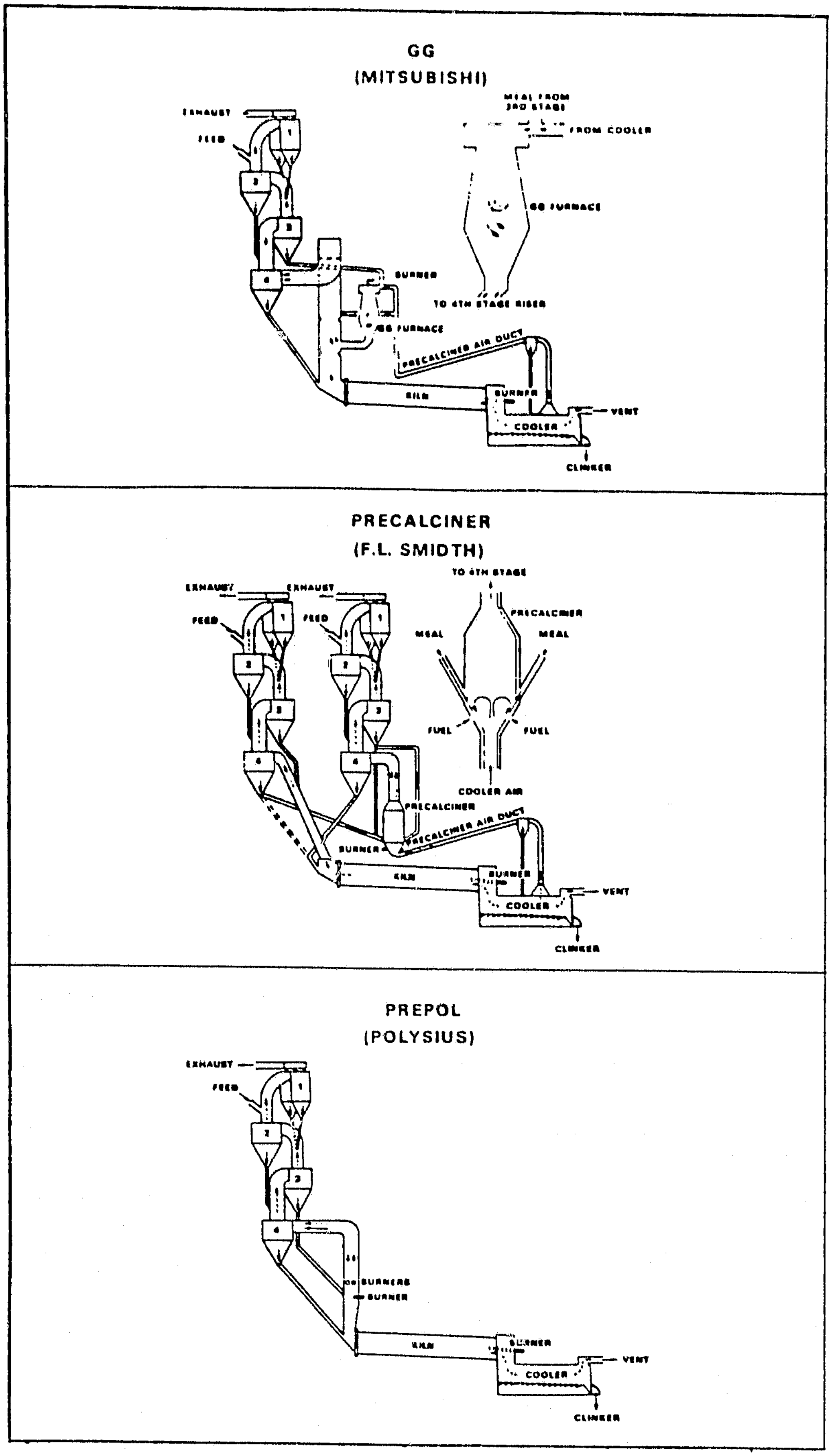


Figure 2 (Cont'd). Precalciner Process

A. Plant SIC/Name/Size: Portland Cement 1.5 million tpy

B. Products:

Product	lb/yr, etc.
Portland Cement - All types	

C. Plant Kilowatt Requirements: Average 20,316 kW; Peak 29,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
Negligible	@			
"	@			
"	@			

E. Other Heat to Process (Describe):

Kiln Burner 649,370 MBTUH

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Roller Mill	2500	3000	900rpm	-	AC Synchronous
I.D. Fans	6400	8000	1200	-	DC or AC Induction
Finish Mill	10,000	10000	200-1200		AC Synchronous

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,600,000	220°F	Kiln/Mill Exit Gas
1,090,000	400°F	Clinker Cooler Waste Gas
11,400,000 BTUH	varies w/ water inlet	Cement Cooler Heat removed by Cooling Water

Plant SIC/Name/Size: Portland Cement 1.5 million TPY

J. Fuels: Primary Fuel Coal / 649,370 mil. Btu/hr (HHV)
Secondary Fuel Oil/Gas / Standby only mil. Btu/hr (HHV)
By-product Fuel Junk / May partially substitute for coal mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS INDUSTRIAL PROCESS DATA SHEETS SIC 3241-2

A. Plant SIC/Name/Size: Portland Cement - 2.0 million tpy

B. Products:

Product	lb/yr, etc.
Portland Cement - All Types	

C. Plant Kilowatt Requirements: Average 27,088 kW; Peak 38,700 kW

D. Steam Requirements (Process & Heating):

lb/hr	@ psig,	Returns %,	Temp. of Returns
Negligible			
"			
"			

E. Other Heat to Process (Describe):

Kiln Burner 865,827 MBTUH

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Roller Mill	3,500	4,000	900 rpm		AC Induction
I.D. Fans	8,800	11,000	1200		DC or AC Induction
Finish Mill	14,000	14,000	200-1200		AC Synchronous

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
2,150,000	220°F	Kiln/Mill Exit Gas
1,450,000	400°F	Clinker Cooler Waste Gas
15,200,000	varies w/ water inlet	Cement Cooler Heat removed by cooling water

SIC 3241-2

Plant SIC/Name/Size: Portland Cement - 2.0 million tpy

J. Fuels: Primary Fuel Coal / 865,827 mil. Btu/hr (HHV)

Secondary Fuel Oil/Gas / Standby only mil. Btu/hr (HHV)

By-product Fuel Junk /May partially substitute for coal mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS INDUSTRIAL PROCESS DATA SHEETS SIC 3241-3

A. Plant SIC/Name/Size: Portland Cement - 1.0 million tpy

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 13,544 kW; Peak 19,348 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
Negligible	@			
"	@			
"	@			

E. Other Heat to Process (Describe):

Kiln Burner 432,913 MBTUH

F. Plant Hours of Operation at Average Conditions: ____________ hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Roller Mill	2000	2500	900		AC Synchronous
I.D. Fans	4400	5500	1200		DC or AC Induction
Finish Mill	6350	6350	200-1200		AC Synchronous

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,075,000	220°F	Kiln/Mill Exit Gas
726,000	400°F	Clinker Cooler Waste Gas
7,600,000 BTUH	Varies w/water inlet	Cement Cooler Heat Removed by Cooling Water

SIC 3241-3

Plant SIC/Name/Size: Portland Cement - 1.0 million tpy

J. Fuels: Primary Fuel Coal / 432,913 mil. Btu/hr (HHV)

Secondary Fuel Oil/Gas / Standby Only mil. Btu/hr (HHV)

By-product Fuel Junk / May partially substitute for coal mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

Increased capacity and replacement = $\frac{(46+35)10^6\ \text{TPY}}{1.5\text{TPY/Plant}}$ between '85 & 2000

= 54 plants

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS INDUSTRIAL PROCESS DATA SHEETS — SIC 3241-4

A. Plant SIC/Name/Size: Portland Cement - 0.5 million TPY

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 6772 kW; Peak 9674 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
Negligible	@			
"	@			
"	@			

E. Other Heat to Process (Describe):

Kiln Burner 216,460 MBTUH

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Roller Mill	1200	1500	900	-	AC Induction
T.D. Fans	2400	3000	1200	-	DC or AC Induction
Finish Mill	4500	4500	200-1200		AC Synchronous

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
538,000	220°F	Kiln/Mill Exit Gas
360,000	400°F	Clinker Cooler Waste Gas
3,800,000 BTUH	Varies w/ water inlet	Cement Cooler Heat removed by cooling water

SIC 3241-4

Plant SIC/Name/Size: Portland Cement - 0.5 million tpy

J. Fuels: Primary Fuel Coal / 216,640 mil. Btu/hr (HHV)

Secondary Fuel Oil/Gas / Standby only mil. Btu/hr (HHV)

By-product Fuel Junk / May partially substitute for coal mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

SECTION 8.4 - 8.6

GLASS INDUSTRY

The following three processes were selected for detailed data gathering and evaluation for CTAS.

Section	SIC Code	Process No.	Description
8.4	3221	1	Container Glass Manufacturing Using Natural Gas and Electric Boosting.
8.5	3211	1	Flat Glass Manufacturing Using Natural Gas.
8.6	3229	1	Pressed and Blown Glass Manufacturing Using Natural Gas and Electric Boosting.

A typical process flow diagram is shown as Figure 1. This diagram is representative of all three processes selected. The detailed data sheets for these three processes are attached to this discussion.

In all processes, the predominant energy requirement is the glass melting portion of the process. The melting requires 75-95% of the total process energy requirements. The glass melting is done at a temperature of 2300-2800°F. At these temperatures, the glass industry processes are not potential front-end cogeneration system candidates. With up to 25% of the energy released as waste heat in the flue gases at 1000°F, the processes do have back-end cogeneration potential if an advanced heat recovery steam generator is introduced that can reliably operate below 1000°F on "duty" flue gas.

In discussions with industry experts, it has been confirmed that the actual fuel used in the glass melting processes is not critical. Oil and natural gas can be substituted for each other with the only process change being different burner and auxiliary equipment requirements. The predominant use of natural gas is due to the lower fuel cost as compared to oil. The use of coal is technically feasible

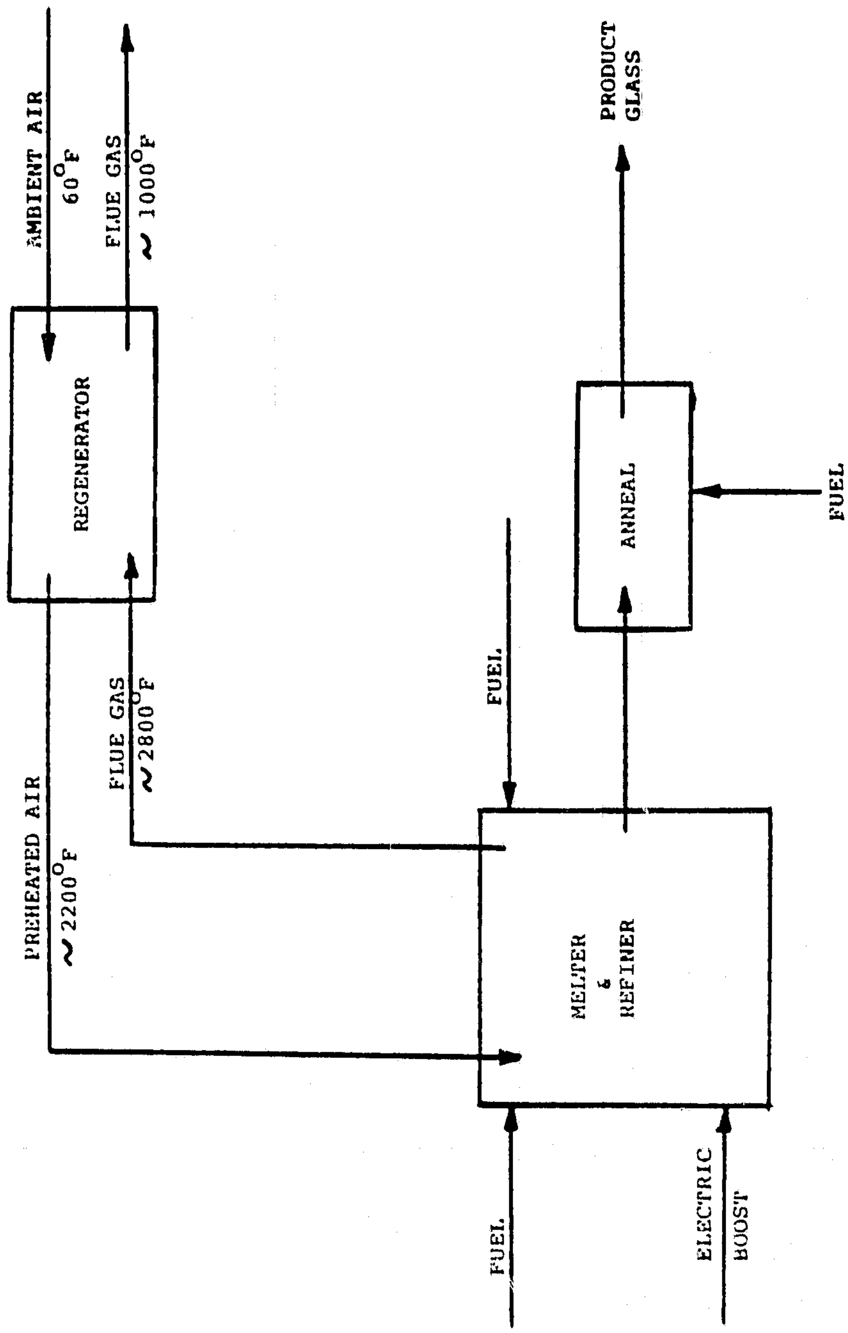
but not currently economically viable due to the high cost of clean-up equipment and gasification equipment.

The plant data submitted is representative of characteristics of new plants that are considered feasible to build today and in the near future. Present fuel costs are high enough to justify additional capital costs for more efficient plants. Accordingly, the typical future glass plant will require on the order of 3000 Btu/lb of glass produced as compared to a current typical figure of 4000-6000 Btu/lb.

The current fuel used in the glass industry is predominantly natural gas due to a combination of fuel price, availability, and cleanliness. Residual and #2 distillate oil could be used if cost competitive. Coal/coal gas could theoretically be used. However, capital cost of coal equipment and exhaust gas clean-up equipment prohibits current usage.

The use of all electric melting or electro-boosting results in higher efficiency plants. However, the faster escalating cost of electricity as compared to natural gas prices has slowed the transition and retrofit to higher efficiency, but higher electrical load plants.

At this point in the study, an estimate of the number of new plants is difficult to determine. Economic conditions, fuel availability, and plant retrofits to boost capacity tend to cloud the actual new plant requirements. However, a 1-2% real growth rate in capacity requirements was assumed. The remainder of added capacity is assumed as being met by electric-boosting and higher productivity.



AMBIENT AIR
60°F
FLUE GAS
~ 1000°F
PRODUCT
GLASS
REGENERATOR
ANNEAL
FUEL
FUEL
PREHEATED AIR
~ 2200°F
FLUE GAS
~ 2800°F
MELTER
&
REFINER
FUEL
ELECTRIC
BOOST

CTAS Plant Data Sheet

Process 3211-1

A. Plant Name/Size: Flat Glass/800 Tons per Day

B. Products:

Product	lb/yr, etc.
Plate Glass	800 Tons/Day

C. Plant Kilowatt Requirements: Average 5600 kW; Peak 7500 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
0	@			
	@			
	@			

E. Other Heat to Process (Describe):
Direct combustion of natural gas (190.0 mmBTU/hr) for 2800°F combustion products.
Hot Gas Flow - 2.16 x 10^6 SCFH at slightly positive pressure

F. Plant Hours of Operation at Average Conditions: 7500 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
4000 HP	7500 HP	1750 rpm	Constant	Motor

Up to 100 - 40 to 75 hp motors

H. Operational Considerations:
Continuous process operation with minimal down time.

Furnace - 75%
Anneal - 15%
Heating and Mechanical - 10%

Energy Use

I. Waste Heat Streams:

lb/hr	Temp.	Description
2.16 x 10^6 SCFH	1000°F	Flue Gas

CTAS Plant Data Sheet

Plant Name/Size: Flat Glass/800 Tons per Day

J. Fuels:

Primary Fuel	Natural Gas	/ 190	mil. Btu/hr (HHV)
Secondary Fuel		/	mil. Btu/hr (HHV)
By-product Fuel		/	mil. Btu/hr (HHV)

K. Fuels Discussion:

Distillate oil is nearly 100% interchangeable with natural gas. Natural gas used due to economic advantages.

L. Applications:

Total No. of Plants in Years 1985-2000	Where	Cogeneration Potential
30-32	Dispersed throughout the country near major population centers. Concentrated slightly in the Mid-West.	Low-Fair

M. Application Discussion:

Cogeneration potential appears low unless an advanced heat recovery steam generator is introduced that can reliably operate below 1000°F on "dirty" flue gas.

N. Preferred Economic Criteria: Return-On-Investment, Discounted Rate of Return

O. Economic Discussion:

Basic glass plant costs are low. Cogeneration has not been economical due to low cost of natural gas. Evaluation could drastically change if natural gas prices are deregulated and fuel cost increases out pace electric rate increases.

P. Duty Cycle and Maintenance Philosophy:

Duty Cycle: 5 days a week - 3 shifts/day at constant production or "pull rate"

Weekends - Furnace maintained at temperature gas flow cut back to approx. 15% flow.

Maintenance Philosophy - Minimal - cycle and equipment are simple. Maintenance only as required. Overhauls at 4-6 year intervals.

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Flat Glass/800 Tons per Day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Low

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process. - Not new

T. What is the national capacity for producing this product

Now in 1978 2.3×10^4 Tons/Day

In 2000 2.7×10^4 Tons/Day

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Increased emphasis on improved efficiency regenerates for air preheat. Increased use of improved insulation and ~~tie~~ fire-brick materials.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Less than the national average.

W. National energy consumed by this process

In 1978 16×10^9 kilowatt-hours equivalent

In 1985 18×10^9 kilowatt-hours equivalent

In 2000 22×10^9 kilowatt-hours equivalent

X. Describe the typical size of this plant today and how that will change in 1985-2000.

800 tons/day - No significant growth

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. - See H,I

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Not available.

CTAS Plant Data Sheet

Process 3221-1

A. Plant Name/Size: Container Glass/450 Tons per Day

B. Products:

Product	lb/yr, etc.
Glass Containers	450 Tons/Day

C. Plant Kilowatt Requirements: Average 5100 kW; Peak 5700 kW

D. Steam Requirements (Process & Heating):

	lb/hr	@	psig,	Returns %,	Temp. of Returns
Process	0	@			
		@			
		@			

E. Other Heat to Process (Describe):

Direct combustion of natural gas (106 mmBTU/hr) for 2800°F combustion products.
Hot Gas Flow - 1.2×10^6 SCFM at slightly positive pressure

F. Plant Hours of Operation at Average Conditions: 7500 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
600 HP		1750 rpm		Motor
Numerous 25-50 HP Motors				

H. Operational Considerations:

Majority of energy requirements are in the glass furnace. Heating and mechanical loads are slight.

Energy Use
80% Furnace
15% Anneal
5% Heating and Mechanical

I. Waste Heat Streams:

lb/hr	Temp.	Description
1.2×10^6 SCFH	1000°F	Flue Gas

CTAS Plant Data Sheet

Plant Name/Size: Container Glass/450 Tons per Day

J. Fuels: Primary Fuel Natural Gas / 106.05 mil. Btu/hr (HHV)

Secondary Fuel / mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

Natural gas used exclusively in this type of plant due to low fuel cost and simplicity of auxiliary equipment. Distillate oil could generally be used if cost competitive.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential
8-12	Throughout U.S.	Low

M. Application Discussion:

Transportation cost of glass containers is high. Accordingly, plants are and will be dispersed throughout the U.S. near to local demand. Cogeneration potential appears low due to basic low capital cost of plants, little electric demand, and little need for low grade heat. Cost of natural gas vs. electricity could alter potential if cost ratio significantly changes.

N. Preferred Economic Criteria: Return-On-Investment, Discounted Rate of Return

O. Economic Discussion:

Basic glass plant costs are low. To date cogeneration has not been economical. Evaluation could be drastically changed by natural gas price deregulation making fuel savings more important - provided electric rates don't keep pace.

P. Duty Cycle and Maintenance Philosophy:

Duty Cycle: 5 days a week - 3 shifts/day at constant production rate or "pull rate"
Weekends - Furnace maintained at temperature, gas flow cut back to approx. 15% flow.

Maintenance Philosophy: Minimal - Cycle is simple as is equipment. Maintenance only as required. Overhauls at 4-6 year intervals.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

See attached.

CTAS Plant Data Sheet

Plant Name/Size: Container Plant/450 Tons per Day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Low

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Not new.

T. What is the national capacity for producing this product

Now in 1978 16×10^6 tons/year

In 2000 20×10^6 tons/year

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Increased use of waste heat recovery for air preheat. Requires better regenerator design due to particulate carryover in flue gas.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Slow growth due to replacement by plastic and possible impact of bottle laws. Basically, not a growth industry.

W. National energy consumed by this process

In 1978 44×10^9 KWHR equivalent

In 1985 41×10^9 KWHR equivalent

In 2000 34×10^9 KWHR equivalent

X. Describe the typical size of this plant today and how that will change in 1985-2000.

Typical size is 450 tons/day. No significant change in the future is foreseen. Transportation not production costs are critical factors.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. - See H and I

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Not available - This figure is proprietary in this very competitive field.

CTAS Plant Data Sheet

Process 3229-1

A. Plant Name/Size: Pressed and Blown Glass/120 Tons per Day

B. Products:

Product	lb/yr, etc.
Lamp Tubes	120 Tons/Day

C. Plant Kilowatt Requirements: Average 1100 kW; Peak 1300 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
0	@			
	@			
	@			

E. Other Heat to Process (Describe):
Direct combustion of natural gas (30 mmBTU/hr) for 2800°F combustion products.
Hot Gas Flow - 0.32×10^6 SCFH at slightly positive pressure

F. Plant Hours of Operation at Average Conditions: 7500 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
200 HP		1750 rpm	Constant	Motor

Miscellaneous small motor drives

H. Operational Considerations:
Majority of energy requirements are in the furnace.

Energy Use
- Furnace - 85%
- Anneal - 8%
- Heating and Mechanical - 7%

I. Waste Heat Streams:

lb/hr	Temp.	Description
0.32×10^6 SCFH	1000°F	Flue Gas

CTAS Plant Data Sheet

Plant Name/Size: Pressed and Blown Glass/120 Tons per Day

J. Fuels: Primary Fuel Natural Gas / 30 mil. Btu/hr (HHV)
Secondary Fuel / mil. Btu/hr (HHV)
By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

Natural gas normally used due to economics. Distillate could essentially be used as a substitute if cost competitive.

L. Applications:

New No. of Plants in Years 1985-2000	Where	Cogeneration Potential
15-20	Throughout U.S.	Low

M. Application Discussion:

Plants are small in size and "cheap" to build. Cogeneration not attractive to date.

N. Preferred Economic Criteria: ROI, DRR

O. Economic Discussion:
Cogeneration not attractive to date due to small plant sizes, electrical requirements, and low gas rates.

P. Duty Cycle and Maintenance Philosophy:

Constant load operation 5 days a week. Reduce to 15% energy requirement to maintain furnace temperature on weekends. Minimal overhaul required.

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

Plant Name/Size: Pressed and Blown Glass/120 Tons per Day

R. Describe the level of capital investment in this industry. (1985-2000 time period)

Low

S. If this is a new process that is not commercial in 1978, give an estimate of the commercial date for this process.

Not new

T. What is the national capacity for producing this product

Now in 1978 2.2×10^4 tons/day

In 2000 3.0×10^4 tons/day

U. Make estimates of changes likely to be made in this process between 1978 and 2000 to be compatible with anticipated environmental regulations, energy conservation measures, changes in raw materials (feedstocks) or other factors that might effect the energy conversion system requirements.

Increased use of regenerators and air preheaters. Increased expenditures for insulation.

V. Describe growth trends for the process products and anticipated future use of the process. (1985-2000 time period)

Slower growth than the national average.

W. National energy consumed by this process

In 1978 20×10^9 KW-HR equivalent

In 1985 18×10^9 KW-HR equivalent

In 2000 15×10^9 KW-HR equivalent

X. Describe the typical size of this plant today and how that will change in 1985-2000.

No significant change from the 120 tons/day size.

Y. Make a list of unit operations in the plant and indicate the major energy users or major sources of waste energy. - See H and I

Z. Describe the cost of energy (heat plus kilowatts) as a percent of the total operating costs. Give basis for this discussion.

Not available.

9.0 - PRIMARY METALS INDUSTRIES 3312

9.1 General

The primary metals industries is composed of the integrated steel mills, the mini-steel mills and the specialty steel mills. For the purpose of this synthesis on the cogeneration of energy, the following analysis encompasses all three subdivisions of the primary metals industries; consequently only specific information regarding a particular description of a steel mill will be individually related. This commentary will discuss greenfield construction, round-out expansions and modifications, estimated capital expenditures, major energy uses, energy conservation, environmental regulation changes, earliest anticipated commercial use and degree of implementation of new facilities, average energy consumed per unit and thermal/electric potential heat losses. The specific data will describe the individual plant capacities and production, growth trends, national energy consumed and the particular range of existing plant capacities, typical modern facilities and the estimated conventional plant size in 1985-2000 period.

A thorough research of various governmental and private documented reports, and prophetical articles written by industrial economists and respected industrial leaders of the steel industry has developed the conclusion that the existing domestic steel manufacturing industry will not keep pace with the world steel demand in 1985-2000. The steel industry has two approaches to the above problem. One, greenfield site construction and the other; domestic rounding-out expansions and modifications. It is of general opinion that the present domestic steel prices, depreciation and investment

tax credit conditions and the current environmetal regulations inhibit greenfield site construction and operation. Regarding round-out programs, their final effect is a temporary and limited solution to the world steel demand. Through the 1978-2000 period round-out programs are expanding raw material facilities (i.e., Coke Oven Batteries), iron and steel making facilities (blast furnaces and electric furnaces), rolling and shaping facilities (continuous casting and annealing furnaces) and finishing facilities (pickle and shear/grinding lines). The cost of greenfield construction and round-out programs has been expressed as a percentage above a projected market price of steel products, and as a cost per unit ton of raw steel and finished steel.

It has been estimated that the cost of greenfield construction will remain above the projected market price of steel by 9 percent - 14 percent. The cost per unit ton of raw steel was estimated at $430/ton, which concludes a $542/ton of finished steel product at 100 percent utilization. A lower utilization factor would increase the cost per unit ton. The cost per unit ton will vary according to the type of facilities installed and the amount of utilization. Depending on many factors which have been considered, the best estimate of capital expenditures is a range from $\$60.0 \times 10^9$ - $\$115 \times 10^9$ by the year 2000. The majority of this estimate will be spent for raw materials, engineered equipment and energy requirements. Energy demands will be made up by coal natural gas, oil/liquid petroleum gas, oxygen and purchased electricity. The cost per dollar for additional greenfiled or round-out programs is estimated to be 0.062$/$ added. This is based on the current cost of energy and the anticipated cost per ton of additional steel manufacturing facilities.

The major energy users of the previously stated fuels are as follows, respectively:

Coke ovens will use 63 percent of the steel industries fuel. Blast stoves, power generation systems, soaking pits and reheating furnaces will use 16.6 percent. Melting and annealing furnaces and heating ovens will absorb 6.3 percent and the BOF, blast and open hearth furnaces use 1.3 percent. Finally, electric furnaces will use 12.5 percent.

The potential for energy conservation in the steel industry is separated into two categories, existing technology and new technology. It is imperative that the following data is understood to be developed from a set of assumptions generally derived from averages across the steel industry. This data cannot be applied to any one particular plant or group of plants. Implementation of a cogeneration system will have to be on a plant by plant basis. The total average potential energy savings is 570×10^{12} Btu/yr providing implementation of improvements to existing technologies and application of new technologies. The potential energy savings for existing technologies is 395×10^{12} Btu/yr and for new technologies is 175×10^{12} Btu/yr. These potential energy savings may be acquired by increasing the efficiency of reheat and annealing furnaces, computer modeling, increase use of continuous casting, dry quenching coke, desulfurization of the blast furnace hot metal, increase the efficiency of the soaking pits, injection of coal into the blast furnaces, conservation of the blast furnace gas, utilization of the BOF gas and the preheating of coking coal. The realization of the improvements to existing and new technologies will

depend on the absence of government intervention, involvement of government energy conservation/environmental control regulations and government established effective incentives. Lack of or delay to any of the above governmental policies will reduce the potential energy savings by 50 percent.

The total national energy consumed in the base year of 1973 and projected to 1985-2000 is 25.0×10^6 Btu/ton. The existing steel manufacturing facilities and their projected round-out programs will consume about 5.0×10^{15} Btu's based on an 80 percent utilization factor.

Regarding thermal/electrical load profiles, energy flow schematics and mass flows; the only developed and documented information available is the major heat losses that are associated with specific intra-steel plant facilities. They are as follows:

Sinter Plants	2.10^6 - 3×10^6 Btu/ton
Coke Plants	0.26×10^6 - 0.52×10^6 Btu/ton
Blast Furnace	1.5×10^6 - 2.0×10^6 Btu/ton
Open Hearth	0.45×10^6 - 0.80×10^6 Btu/ton
Electric Furnace	0.31×10^6 Btu/ton

9.2 Integrated Steel Mill (3325-1)

Integrated steel plants utilize iron ore and metalurgial coal as major raw materials. They transform these into steel by a series of processes which include coke making, sintering, reduction of ore by blast furnaces and steel making by either a BOF, electric furnace or open hearth. Further manufacturing forms raw steel by continuous casting methods, which is then worked into steel products by rolling, shearing and finishing facilities.

The range of existing integrated steel mills is 1.0×10^6 tpy to 28×10^6 tpy which includes multiple plant corporations. The current domestic average capacity of the integrated steel plants is 118×10^6 tpy. Based on the present utilization factor* of 80%, they produce about 94×10^6 tpy. The typcial size of the integrated steel mills is 2.5×10^6 tpy. The expected plant size by the period 1985-2000 is 4.0×10^6 tpy.

* Utilization factor is defined as the capability to produce raw steel
* for a full book order based on the current availability of raw mate-
* rials, fuels and supplies and of the industries coke, iron steel
* making, rolling and finishing facilities, recognizing current envi-
* ronmental and safety requirements.

9.3 Steel Specialty Plant (3312-1)

The steel specialty plants are very similar in design to the non-integrated steel mills. The major difference is the type of steel they process; which is special alloy and stainless steel products.

The range of existing steel specialty plants is 8000 tpy to 1.15×10^6 tpy. This also includes multi-plant corporations. The current domestic average capacity of the steel specialty mills is 21×10^6 tpy. Based on the present utilization factor, their production is 17×10^6 tpy. The typical size of steel specialty plants is 200,000 tpy. Their expected plant size in the period 1985-2000 is 300,000 tpy.

9.4 Non-Integrated Steel Mill (3325-4)

A non-integrated steel mill is referred to as mini-plants which use ferrous scrap as their primary raw material. Electric furnaces are their major equipment for steel making. Further steel processing is very similar

to the integrated plants only its diversification and onnage of steel products distinguishes it from integrated mills. Because of their high demand for electricity, only non-integrated steel and specialty steel mills are critically effected by increase of prices and shortages of kilowatt power.

The range of the non-integrated steel mills (mini-plants) is 18,000 tpy to 1.25×10^6 tpy. The current domestic average capacity of the mini-plants is 14×10^6 tpy. Based on the present utilization factor*, their production is 11×10^6 tpy. The typical size of the mini plants is 250,000 tpy. Their expected plant size for the years 1985-2000 is 400,000 tpy.

CTAS Plant Data Sheet

A. Plant Name/Size: Integrated Steel Mills/2.5 x 10^6 TPY

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average .28 x 10^6 kW; Peak .33 x 10^6 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
870,000	@	400	unknown	unknown
42,000	@	200	unknown	unknown
	@			

E. Other Heat to Process (Describe):

Blast furnace air is supplied at 4500 lbs/t at 1400° F.

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed RPM	Speed Range RPM	Probable Driver
8100	10,000	300	150-450	Syn. motor
4800	6,000	150	100-230	V.S./D.C. motor
2800	3,500	350	200-500	Motor generator

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1.97 x 10^6	800°F	Blast Furnace Emissions
0.603 x 10^6	2300°F	BOF Emissions
0.54 x 10^6	1600°F	Open Hearth Emissions
.435 x 10^6	1800°F	Coke Oven Emission

CTAS Plant Data Sheet

Plant Name/Size: Integrated Steel Mills/2.5 x 10^6 TPY

J. Fuels: Primary Fuel Coking Coal / 1.04 x 10^4 (BTU) mil. Btu/hr (HHV)
Secondary Fuel Natural Gas / 0.19 x10^4 (BTU) mil. Btu/hr (HHV)
By-product Fuel Coke Oven Gas / 0.18 x 10^4 (BTU) mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Specialty Steel Mill/200,000 TPY

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 60,000 kW; Peak 80,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
89,000	@	400	unknown	unknown
4,200	@	200	unknown	unknown
	@			

E. Other Heat to Process (Describe):

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed RPM	Speed Range RPM	Probable Driver
1150	1750	450	300-600	Motor generator
2100	3000	290	161-420	Motor generator
3100	4500	800	690-960	V.S./D.C. motor

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
5000	1800°F	Electric furnace off gas

CTAS Plant Data Sheet

Plant Name/Size: Specialty Steel Mill/200,000 TPY

J. Fuels: Primary Fuel Purchased Electricity / 0.328 (3.41×10^3 $\frac{Btu}{kwhr}$) mil. Btu/hr (HHV)

Secondary Fuel Natural Gas / 0.015×10^4 mil. Btu/hr (HHV)

By-product Fuel None / N/A mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Mini Steel Mill / 250,000 TPY

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 40,000 kW; Peak 50,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
87,000	@	400	unknown	unknown
4,200	@	200	unknown	unknown
	@			

E. Other Heat to Process (Describe):

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range RPM	Probable Driver
720	800	800 RPM	450-1350	SYN. Motor
4,100	4,500	800 RPM	690-960	V.S./D.C. motor

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
6000	1800°F	Electric furnace off gas

CTAS Plant Data Sheet

Plant Name/Size: Mini Steel Mill / 250,000 TPY

J. Fuels:

Primary Fuel	Purchased Electricity	/ 0.41 (3.41 x 10^3 BTU/kwh)	mil. Btu/hr (HHV)
Secondary Fuel	Natural Gas	/ 0.018 x 10^4	mil. Btu/hr (HHV)
By-product Fuel	None	/ N/A	mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate. Use additional sheets for discussion where required.

9.5 NARRATIVE REPORT - ALUMINA

A. The 4-digit SIC industry to which the alumina process belongs is 2819. **Note: Will be listed as 3334**

B. It is estimated that the level of capital investment in this industry in the 1985-2000 time period will be $9.5 billion. This estimate is based on the addition of 13,025,000 metric tons of annual alumina production capacity at a cost of $730/metric ton.

C. General Process Description

General Description of the process as it will be in the 1985-2000 time period.

Alumina will probably continue to be produced from bauxite by the well known Bayer Process in the 1985-2000 time period. The process will probably be modified to utilize more heat transfer area to reduce the amount of energy consumed. Also, the process will probably be modified to reduce losses of bauxite as the price of bauxite increases.

In the Bayer process bauxite is dissolved in hot caustic soda solution, clarified to remove undissolved solids, the alumina hydrate precipitated and the hydrate calcined to produce alumina.

C. 1. Input materials for this process for the production of two pounds of alumina are:

4 pounds of bauxite
1/2 pound of caustic soda
1/8 pound of lime

C. 2. Product output for this process is 2 pounds of alumina per 4 pounds of bauxite consumed.

C. 3. Listing of unit operations for the alumina process are:

(1) Mixing

In a typical Bayer process plant bauxite is mixed with lime and hot, 212+°F spent liquor to form a slurry. The slurry is screened and is heated to a temperature of 325+°F. The heated slurry is then pumped to the digestor vessels.

(2) Digestion

The hot slurry from the pumps is mixed with a stream of 400+°F spent liquor as it enters the digestor vessels. The mixture is further heated to a temperature of 450+°F and a pressure of

500+ psig by the injection of live steam. At this pressure and temperature most of the alumina is extracted and the inert materials remain suspended by mixers in the digestor vessels. Silica scale deposits in the first digestor vessels.

The alumina-bearing "pregnant liquor" is cooled in a series of pressure reducing flash stages to atmospheric pressure and 212+°F. The flashing steam is used to heat the digestion spent liquor in heat exchangers which operate in series. Final heating of the liquor is accomplished by direct steam injection prior to mixing with the bauxite slurry.

The pregnant liquor is pumped to the Clarification and Filtration Areas, where the undissolved solids are removed prior to precipitation of the alumina hydrate.

(3) Clarification

Coarse undissolved solids are removed from the liquor by sand traps and the bulk of the remaining finer solids are removed by settling. Settled mud solids and sand are washed to remove caustic liquor before the mud is pumped to the disposal facilities. The wash water is returned to the process to cool and dilute the digestion effluent. Clarified liquor is pumped to the filtration facility for further solids removal.

Clarified pregnant liquor is mixed with filter aid and filtered in filter presses. A filter cake builds up on the filter cloth until its thickness has too much resistance to liquor flow. The press is then opened and the cake sluiced off and sent to the Clarification Area mud washers. Filter effluent, which now contains a minimum of suspended solids, is sent to the Heat Interchange Area for cooling before precipitation.

(4) Heat Interchange

The filtered pregnant liquor, at 210+°F, is too hot for precipitation of hydrate and it is, therefore, flash cooled in the Heat Interchange facility. This consists of trains of flash tanks and heat exchangers. Filtered liquor is pumped to the vacuum flash tanks and is withdrawn from the last flash tanks at approximately 160 to 170°F and sent to the Precipitation Area.

(5) Precipitation

Cooled pregnant liquor flows through a series of precipitation vessels in which it is agitated in the presence of alumina hydrate seed to precipitate alumina trihydrate. The precipitated hydrate is formed in a range of particle sizes which are separated in settling tanks. The product hydrate, which is the largest crystal fraction, separates first and the slurry is pumped to the Calcination Area for washing and calcining to product alumina. The remaining fractions are reused as seed.

(6) Calcination

The coarse alumina hydrate from the primary classifiers in the Precipitation Area is washed in dilution tanks and then on vacuum filters to remove caustic liquor. The moist, washed hydrate is then fed to kilns for heating to 2400°F and conversion to product alumina.

The alumina is cooled to 200°F by air and water cooled heat exchangers before being conveyed to storage bins for loadout to shipping vessels.

(7) Evaporation

The spent liquor which leaves the Precipitation Area is too dilute for use in the digestion vessels. The required concentration of caustic soda is obtained by flashing off water from the spent liquor, which has been heated in Heat Interchange heaters, in a series of vacuum flash tanks with associated heat exchangers.

The evaporated spent liquor is stored in tanks and is then pumped to the digestion vessels via the digestion heat exchangers.

C. 4. Major energy uses in the Bayer alumina process are: steam to the digestors which, in some plants, must be at a pressure in the 635 psig range; fuel to fire the calcination kilns which operate in the 2000°F range and require a clean fuel such as natural gas or fuel oil to prevent contaminating the product alumina; plant steam in the 90 psig range for general plant use and for heating process streams;

fuel for the generation of electric power to run the motors which drive the pumps, mixers, conveyors, fans, compressors, etc., required by the process.

C. 5. Power failures are not considered to be critical to the safe operation of an alumina plant since such plants are designed to fail safe. After restoration of the power to an alumina plant it can be put back into operation in a relatively short period of time, with only minor losses of product. Of course, operations such as precipitation and calcination are adversely affected by power loss, and if the loss were for an extended period of time could require considerable maintenance labor to clean equipment to prevent plugging.

C. 6. Cogeneration is a common practice in alumina plants because large quantities of steam are used for the various processes within the facility. The turbine generators, either straight back pressure or automatic extraction condensing units, act as the reducing valves for the digestor, compressor and deaerator.

D. For Processes currently in use:

D. 1. The approximate national alumina industry cacpcity is 11,868,000 metric tons and the production is 10,681,200 metric tons.

D. 2. The estimated changes likely to be made to the Bayer process for the production of alumina is the use of additional heat transfer surface area in order to reduce the amount of energy consumed. In some cases as much as one-third of the energy can be saved by this method. Also, in some cases, equipment will be added to reduce the loss of alumina in waste streams. This will become increasingly feasible as the price of bauxite increases.

D. 3. Growth trends show an estimated 17,043,000 metric tons of Bayer process alumina capacity in 1985 and 30,068,000 metric tons in 2000.

E. It is unlikely that any process other than the Bayer process will be used in the 1985-2000 time period.

F. The total estimated national energy consumed by the Bayer alumina process in 1978 is 2.13 X 10^{14} Btu, in 1985 will be 3.05 X 10^{14} Btu and in 2000 will be 5.39 X 10^{14} Btu.

G.

G. 1. The average energy consumption per metric ton of alumina production is 17.91 X 10^6 Btu.

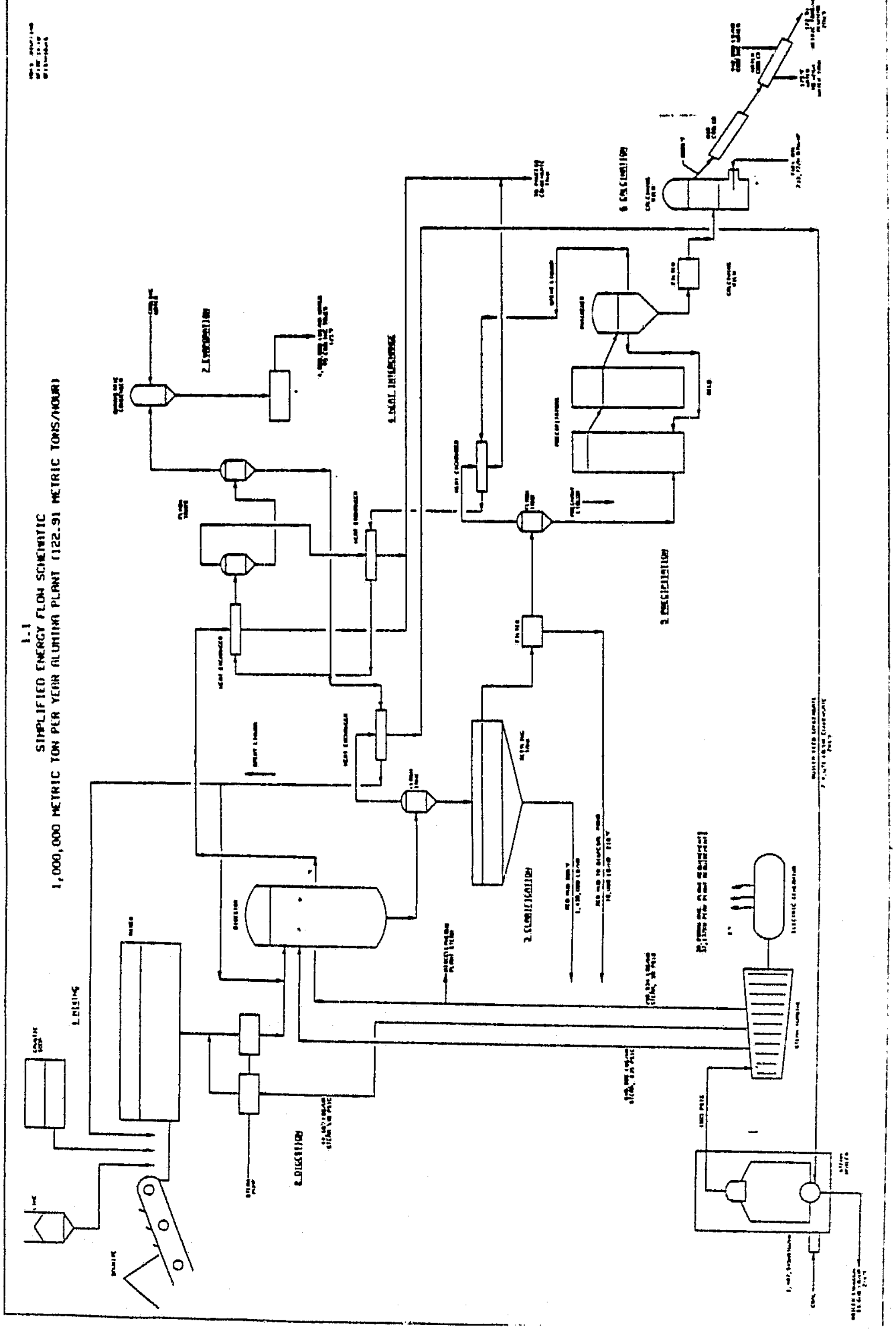
G. 2. The current cost of energy per dollar value added is approximately $0.36.

H.

H. 1. The range of existing plant capacities is from 180,000 to 950,000 metric tons per year.

H. 2. The capacity of plants representative of typical modern facilities is 1,000,000 metric tons per year.

H. 3. The expected typical plant size during the period 1985-2000 is from 1,000,000 to 2,000,000 metric tons per year.



1.1
SIMPLIFIED ENERGY FLOW SCHEMATIC
1,000,000 METRIC TON PER YEAR ALUMINA PLANT (122.91 METRIC TONS/HOUR)

KEY PROCESS CHARACTERISTICS OF 1,000,000 METRIC TON/ALUMINA PLANT

2819-1
WAS 3334-5

PLANT HOURS OF OPERATION	8136 HOURS/YEAR @ AVERAGE CONDITIONS	
PLANT ELECTRICAL REQUIREMENTS	30,290 KILOWATTS NORMAL	37,137 KILOWATTS PEAK

PLANT STEAM REQUIREMENTS

LBS/HR	@ PSIG	RETURNS %	TEMPERATURE OF RETURNS
295,934	50	0	-
44,100	500	100	284 °F
640,506	635	635	284 °F

OTHER HEAT TO PROCESS	733,772 M BTU/HR TO ALUMINA HYDRATE CALCINER

LARGE HORSEPOWER LOADS (TYPICAL)

NORMAL HP	PEAK HP	SPEED, RPM	SPEED RANGE, RPM	PROBABLE DRIVER
150 TO 1000	200 TO 1500	1200	1200	ELECTRIC MOTORS

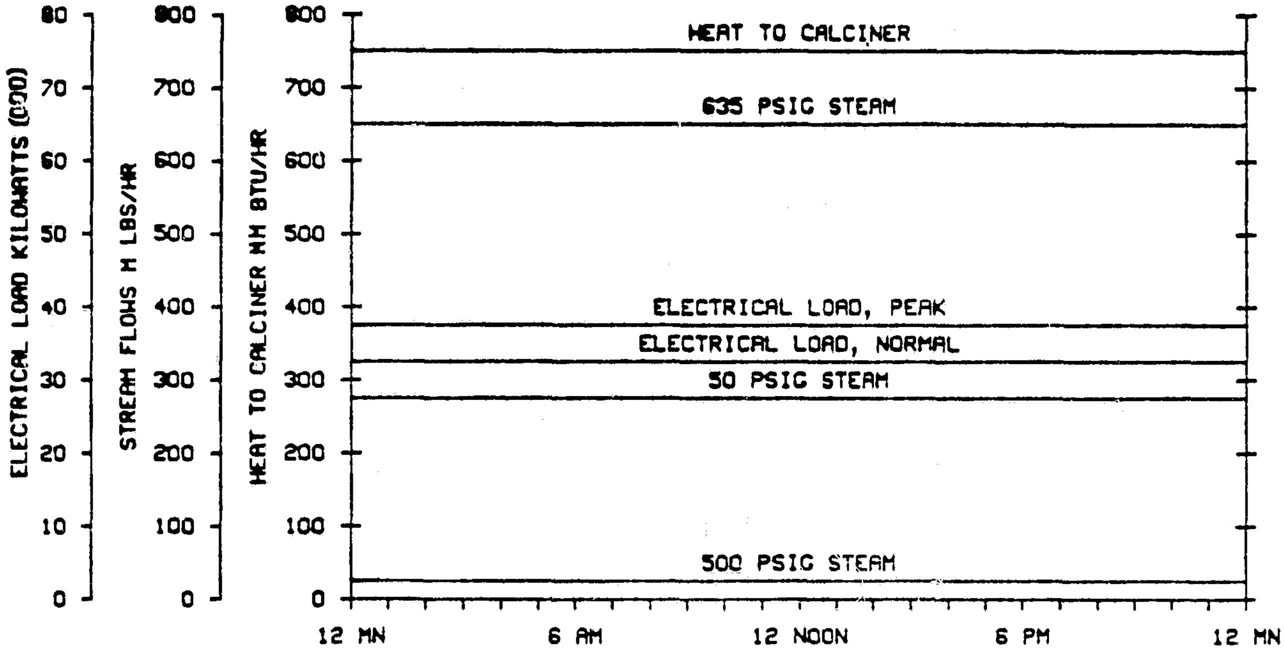
FUELS	DESCRIPTION	MILLION BTU/HR (HHV)
PRIMARY	COAL OR FUEL OIL	1467.5
SECONDARY	FUEL OIL OR NAT. GAS	733.8
BY-PRODUCT	NONE	-

WASTE HEAT STREAMS

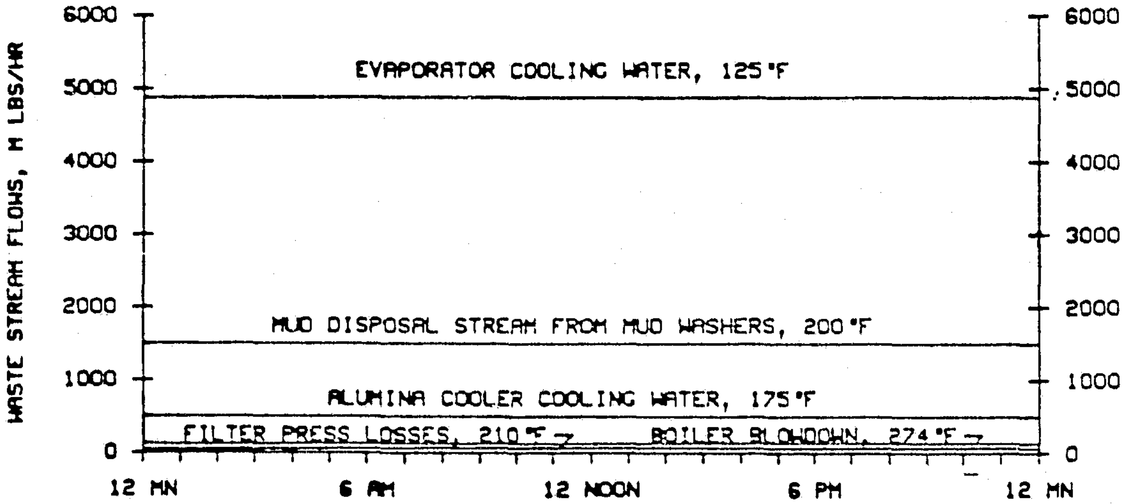
DESCRIPTION	LBS/HR	TEMP., °F	SUITABLE FOR USE AS MAKEUP WATER	SUITABLE FOR HEAT RECOVERY
EVAPORATOR COOLING WATER	4,950,000	125	YES	NO
MUD DISPOSAL STREAM FROM MUD WASHERS	1,430,000	200	NO	NO
COOLING WATER FROM ALUMINA COOLER	442,000	175	YES	YES
BOILER BLOWDOWN	83,600	274	NO	YES
FILTER PRESS LOSSES	10,000	210	NO	NO

,D: 1 DISK: 140
DF: AD7139:D
SF: SYM100:S

I.3.1
THERMAL AND ELECTRICAL LOAD PROFILES ON PROCESS UTILITY REQUIREMENTS FOR A TYPICAL, NORMAL WORK DAY FOR A 1,000,000 METRIC TON/YEAR ALUMINA PLANT



I.3.2
PROFILE OF WASTE HEAT STREAMS FOR A TYPICAL NORMAL WORK DAY FOR A 1,000,000 METRIC TON/YEAR ALUMINA PLANT



CTAS Plant Data Sheet

A. Plant Name/Size: Alumina Plant 1,000,000 metric tons per year

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 30,290 kW; Peak 37,137 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
295,934	@	50	0	—
44,100	@	500	100	284°F
640,506	@	635	100	284°F

E. Other Heat to Process (Describe):

733,772 M Btu/Hr. to Alumina Hydrate calciners
This heat must be supplied by either fuel oil or nat. gas to prevent contamination of the product, alumina.

F. Plant Hours of Operation at Average Conditions: ________ hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Pumps	150 to 1000	200 to 1500	1200 RPM	1200 RPM	Electric Motors

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
83,600	274°F	Boiler Blowdown
442,000	175°F	Cooling Water Return From Alumina Cooler
1,430,000	200°F	Mud Disposal Stream From Mud Washers
4,950,000	125°F	Evaporator Cooling Water
10,000	210°F	Filter Press Losses

CTAS Plant Data Sheet

Plant Name/Size: Alumina Plant 1,000,000 metric tons per year

J. Fuels: Primary Fuel Coal or Fuel Oil / 1,467.5 mil. Btu/hr (HHV)

Secondary Fuel Fuel Oil or Nat.Gas / 733.8 mil. Btu/hr (HHV)

By-product Fuel None / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria: __________

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Alumina Plant 2,000,000 metric tons/year

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 60,580 kW; Peak 74,274 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
591,868	@	50	0	--
88,200	@	500	100	284°F
1,281,012	@	635	100	284°F

E. Other Heat to Process (Describe):

1,076,800 M Btu/Hr. to Alumina Hydrate Calciners.
This heat must be supplied by either fuel oil or natural gas to prevent contamination of the product, alumina.

F. Plant Hours of Operation at Average Conditions: ________ hr/yr

G. Large Horsepower Loads:

	Normal hp	Peak hp	Speed	Speed Range	Probable Driver
Pumps	150 to 1000	200 to 1500	1200 RPM	1200 RPM	Electric Motors

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
167,200	274° F.	Boiler Blowdown
884,000	175° F.	Cooling Water Return From Alumina Cooler
2,860,000	200° F.	Mud Disposal Stream From Mud Washers
9,900,000	125° F.	Evaporator Cooling Water
20,000	210° F.	Filter Press Losses

CTAS Plant Data Sheet

Plant Name/Size: Alumina Plant 2,000,000 metric tons/year

J. Fuels: Primary Fuel Coal or Fuel Oil / 2,935.1 mil. Btu/hr (HHV)
Secondary Fuel Fuel Oil or Nat.Gas / 1,467.6 mil. Btu/hr (HHV)
By-product Fuel None / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

9.6 NARATIVE REPORT - ALUMINUM SMELTING

A. The 4-Digit SIC industry to which the aluminum smelting process belongs is 3334.

B. The estimated approximate level of capital investment in that industry for the 1985-2000 time period is $11.33 billion.

C. General Process Description

Metallic aluminum is produced by the electrolytic reduction of pure alumina into aluminum and oxygen in a bath of fused cryolite. It is not possible to reduce alumina with carbon because, at the temperature required for this reduction, the aluminum comes off as a vapor and is carried away with the carbon monoxide. This metallic vapor cannot be condensed by cooling because the reaction reverses at lower temperatures and then converts the aluminum back to alumina.

The basic aluminum smelting process used today is the same one discovered by Hall in 1886. In this process alumina is dissolved in a bath of molten cryolite - sodium aluminum fluoride - in large electric furnaces known as pots. A number of these pots which are deep, rectangular steel shells lined with carbon, are connected electrically in series. This series of pots is known as a potline.

High-amperage, low-voltage direct current is passed through the cryolite by means of carbon anodes suspended in each pot to the bottom of the pot, which acts as a cathode. The electricity decomposes the dissolved alumina with the molten aluminum going to the bottom of the pot and the oxygen combining with the carbon anode to be released as carbon dioxide. The layer of molten aluminum which covers the carbon lining at the bottom of the_pot becomes the cathode.

Additional alumina is added to the bath to replace that consumed by reduction. Heat generated by the electric current maintains the cryolite bath in a molten condition so that new alumina charges are dissolved. Periodically molten aluminum is siphoned off. The metal is then cast into ingots.

C. 1. The input materials are 2 lb of alumina, mettalurgical coal and tar, 0.6 lb of baked carbon, 0.3 lb of cryolite, 0.04 lb of aluminum fluoride and 6-8 kwh of electricity.

C. 2. The product output from the above input materials is 1 lb of aluminum metal in the molten state.

C. 3. The unit operations of the aluminum smelting process are:

<u>(1) Anode Making</u>

Very pure carbon is used as the raw material to make anodes. This is necessary to keep from contaminating

the bath in the pot, since all impurities in the anodes dissolve in the bath as the anodes are consumed. The very pure carbon (calcined petroleum coke or pitch coke) is ground and mixed hot with enough coal tar pitch to bond it into a solid block when it is pressed in a mold to form the "green" anode. This is then baked slowly at temperatures rising to a maximum of 2012-2372°F, and cooled slowly, all out of contact with the air. In a cavity, molded in the top of each block, a steel stub is enbedded by casting molten iron around it; the conducting bar is bolted to this stub. This is the prebaked electrode to distinguish it from the Söderburg electrode, in which the electrode (one large one per pot) is formed in place and is baked by heat from the pot as it gradually decends into the pot. The paste charged into the top of the Söderberg electrode is a carbon - pitch mixture similar to that used for a prebaked electrode, but with a somewhat large proportion of pitch.

(2) Reduction

Alumina is electrolytically decomposed into aluminum and oxygen. The aluminum, in the molten state, is removed from the pot periodically by siphoning. The oxygen reacts with the carbon anodes to form carbon dioxide which is released from the pot as a gas.

(3) Casting

The molten aluminum which has been collected from the pots by siphoning into a crucible is cast into pigs or ingots.

C. 4. The major energy use in the aluminum smelting process is the electricity required by the pots in electrolytically decomposing the alumina. This requires from 6 to 8 kwh of electricity per 1 lb of aluminum produced.

Another major energy use in the process is the heat required to bake the anodes used in the pots. This requires 1462 Btu per lb aluminum produced. This heat must be furnished from fuel oil or natural gas to prevent contamination of the anodes.

C. 5. Power failures are extremely critical in the aluminum smelting process because when the electric current is shut off the molten aluminum in the pots freezes. When this happens, the solid aluminum can only be removed by blasting. This takes months, which means the production of the whole plant is lost for several months.

C. 6. Since most of the energy required by the aluminum smelting process is in the form of electricity and since very little process steam is required, the potential for cogeneration is considered to be nil.

D. For Process Currently In Use.

D. 1. The approximate national industry capacity is 4,824,490 Metric Tons/Yr. while the current production is 4,535,020 Metric Tons/Yr.

D. 2. The Alcoa Smelting Process is now in the pilot plant stage of development. It is too early to speculate on the future of this process at the present time. The process reportedly uses 30% less electrical power than today's most efficient smelters. In this process alumina is converted to anhydrous aluminum chloride which is then electrolytically decomposed into molten aluminum and chlorine. The chlorine is recycled in the process.

D. 3. It is estimated that the aluminum smelting process in the United States will have the following capacity in time period (1985-2000):

1985	7,410,000	Metric Tons
2000	13,073,000	Metric Tons

E. The most promising new aluminum smelting process at the present time appears to be the ASP or Alcoa Smelting Process mentioned in D. 2. above. Since this process is still in the developmental stage, it is unlikely that it will have a significant effect on the aluminum smelting industry in the time period (1985-2000).

F. Total estimated national energy consumed by the aluminum smelting process for 1978 and for the time period (1985-2000) is as follows:

1978	6.5×10^{14} Btu/Yr
1985	10.1×10^{14} Btu/Yr
2000	17.7×10^{14} Btu/Yr

G. The average energy consumption per unit of primary process output.

G. 1. The average energy consumption per pound of aluminum is 6 to 8 kwh of electrical power plus 1462 Btu for baking the carbon anodes, if prebaked anodes are used.

G. 2. Current cost of energy per dollar value added is $0.267.

H.

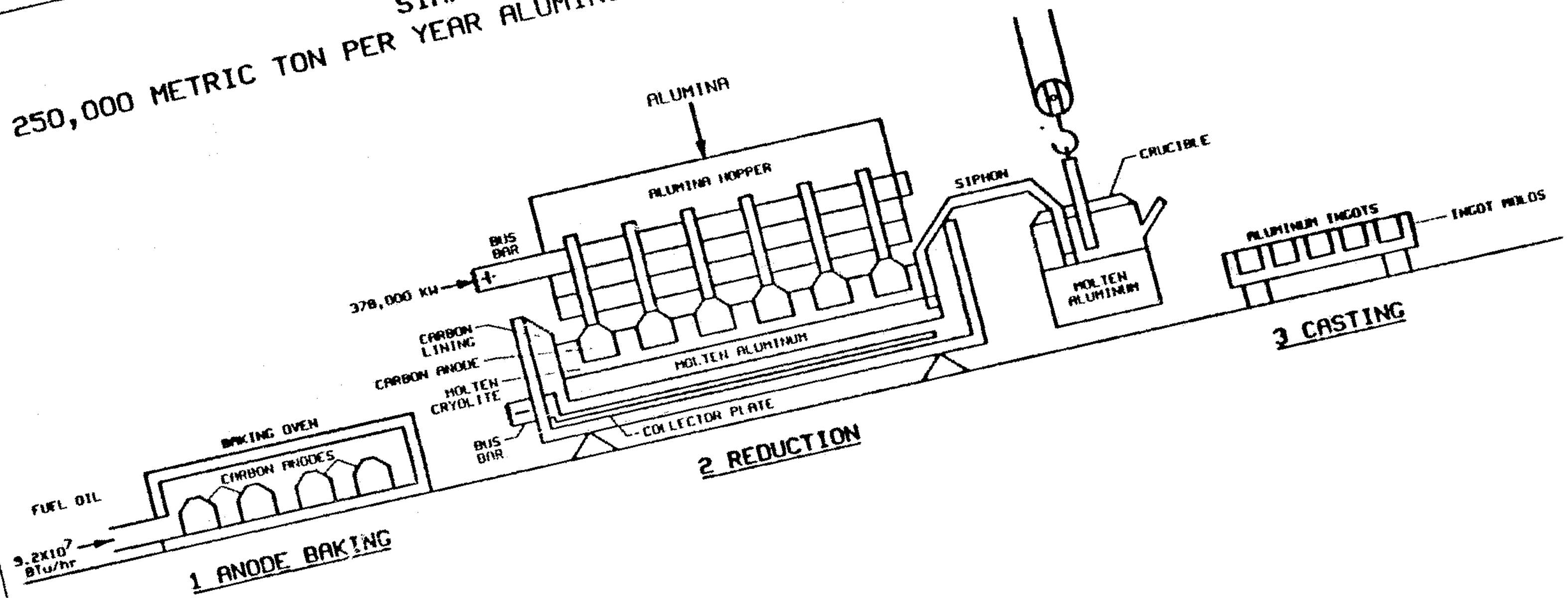
H. 1. The range of capacities of existing aluminum smelting plants is from 27,000 to 259,000 metric tons per year.

H. 2. The capacity of plants representative of typical modern facilities is 125,000 metric tons per year.

H. 3. The expected typical plant size during the period 1985-2000 is 250,000 metric tons per year.

I.1

SIMPLIFIED ENERGY FLOW SCHEMATIC
250,000 METRIC TON PER YEAR ALUMINUM SMELTING PLANT (28.539 METRIC TONS/HOUR)



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I.2
DATA FOR KEY PROCESS CHARACTERISTICS FOR 250,000 METRIC TON PER YEAR ALUMINUM SMELTING PLANT

PLANT KILOWATTS REQUIREMENTS	378,000 KW AVERAGE	378,000 KW PEAK
STEAM REQUIREMENTS	NONE	
OTHER HEAT TO PROCESS	92,000 M BTU/HR TO BAKE CARBON ANODES	

LARGE HORSEPOWER LOADS (TYPICAL)

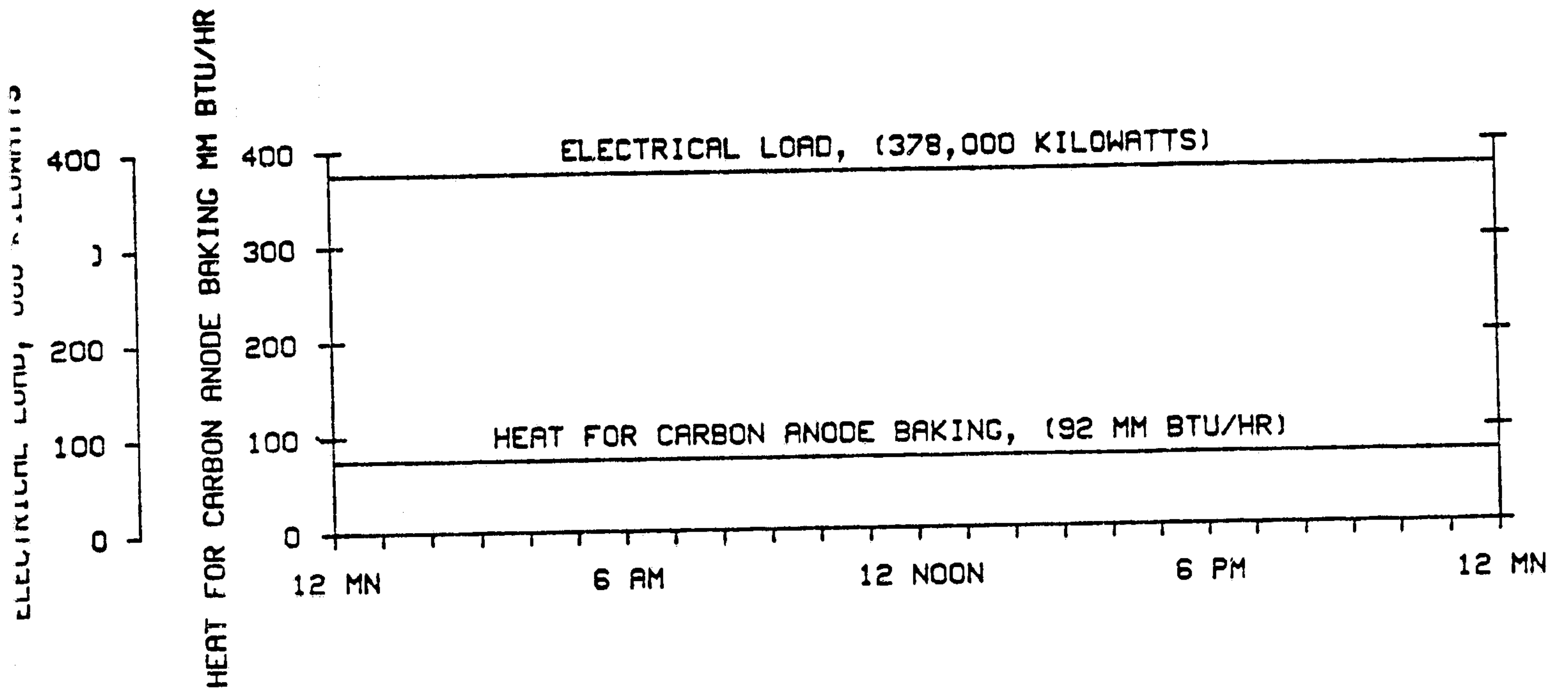
NORMAL HP	PEAK HP	SPEED RPM	SPEED RANGE, RPM	PROBABLE DRIVER
75 TO 750	100 TO 1000	1200	1200	ELECTRIC MOTORS

FUELS	DESCRIPTION	MILLION BTU/HR (HHV)
PRIMARY	FUEL OIL OR NAT. GAS	92
SECONDARY	NONE	
BY-PRODUCT		

WASTE HEAT STREAMS

DESCRIPTION	LBS/HR	TEMP., °F	SUITABLE FOR HEAT RECOVERY
NONE			

THERMAL AND ELECTRICAL LOAD PROFILES ON PROCESS UTILITY REQUIREMENTS FOR A TYPICAL, NORMAL WORK DAY FOR A 250,000 METRIC TON/YEAR ALUMINUM SMELTING PLANT



I.3.2

PROFILE OF WASTE HEAT STREAMS FOR A TYPICAL, NORMAL WORK DAY FOR A 250,000 METRIC TON/YEAR ALUMINUM SMELTING PLANT

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THERE ARE NONE.

CTAS Plant Data Sheet

A. Plant Name/Size: Aluminum Plant 500,000 Metric Tons/Years

B. Products: Product lb/yr, etc.

C. Plant Kilowatt Requirements: Average 756,000 kW; Peak 756,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
None	@			
	@			
	@			

E. Other Heat to Process (Describe):

184,000 M Btu/Hr. to bake anodes

F. Plant Hours of Operation at Average Conditions: ________ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
75 to 750	100 to 1000	1200 RPM	1200 RPM	Elec. Motors

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
None		

CTAS Plant Data Sheet

Plant Name/Size: Aluminum Plant 500,000 metric tons/year

J. Fuels: Primary Fuel Fuel Oil / 184.0 mil. Btu/hr (HHV)
Secondary Fuel None / mil. Btu/hr (HHV)
By-product Fuel None / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Aluminum Plant 250,000 metric tons/yr.

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 378,000 kW; Peak 378,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
None	@	,	,	
	@	,	,	
	@	,	,	

E. Other Heat to Process (Describe):

92,000 M Btu/Hr. to bake anodes.

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
75 to 750	100 to 1000	1200 RPM	1200 RPM	Electric Motors

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
None		

CTAS Plant Data Sheet

Plant Name/Size: Primary Aluminum Plant 250,000 metric tons/year

J. Fuels: Primary Fuel Fuel Oil / 92.0 mil. Btu/hr (HHV)
Secondary Fuel None / mil. Btu/hr (HHV)
By-product Fuel None / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Aluminum Plant 100,000 metric tons/year

B. Products:

Product	lb/yr, etc.

C. Plant Kilowatt Requirements: Average 153,000 kW; Peak 153,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
None	@			
	@			
	@			

E. Other Heat to Process (Describe):

36,800 M Btu/Hr. to bake anodes.

F. Plant Hours of Operation at Average Conditions: ______ hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
50 to 500	75 to 750	1200 RPM	1200 RPM	Elec. Motors

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
None		

CTAS Plant Data Sheet

Plant Name/Size: Aluminum Plant 100,000 metric tons/year.

J. Fuels: Primary Fuel Fuel Oil / 36.8 mil. Btu/hr (HHV)
Secondary Fuel ________ / ________ mil. Btu/hr (HHV)
By-product Fuel ________ / ________ mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria: ________

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

COPPER SMELTING
CTAS PROCESS DESCRIPTION CHECKSHEET
TASK 2-3, NARRATIVE REPORT

9.7

A. The SIC industry code number for copper smelting is 3331.

B. The estimated level of capital expenditure processes in the United States, during the 1985 to 2000 period, will be approximately 800 million dollars, expressed as 1978 dollars.

C. Copper smelting embodies pyrometallurgical treatment of naturally occuring, sulfur-bearing copper mineral species which in most cases have been concentrated by physical means. Some other copper containing materials are co-treated with the sulfides, for example, scrap, cement copper and other secondaries. The input materials other than those mentioned include silica and limestone flux which is required to provide a low melting, fluid slag above the molten copper containing phase.

In smelting of copper sulfides, a matte is produced as an intermediate product; matte contains copper, iron and sulfur as its principal constituents and calcium, magnesium, aluminum and other elements in relatively minor proportions. A second product of copper smelting is blister copper, a product normally containing in excess of 98 percent copper, diluted with oxygen, iron, sulfur, phosphorous and the like. Blister copper is a commericially traded commodity but requires additional treatment before end product consumption.

Other relatively common smelter products are anode or fire refined copper. The former is the normal smelter product, cast into shapes which render it amenable to electrolyic refining. The latter is a somewhat special material that finds direct use for copper in pipe, alloying and casting applications.

Depending upon the smelting method utilized, the principal unit operations in copper smelting include concentrate drying and pelletizing, smelting (melting), converting, anode or fire refining and casting. Water, typically contained in the filter cake, concentrate feed is frequently removed in the roasting operation. The dried material, or calcine, is the product. At this time, a considerable proportion of copper concentrate is directly fed with its moisture to the smelting process. In smelting, the concentrate and fluxes are elevated in temperature to the point where they become molten and form two distinct phases, matte and slag. The latter phase contains iron oxides, calcium and silican oxides and alumina in solid solution; it is a disposable material. The matte is subsequently treated in molten form to extreme oxidation through air blowing which oxidizes both the contained iron and sulfur. The former is removed as a slag and the latter as sulfur dioxide gas. In both anode or fire refining, the relatively pure molten copper is blown with air to remove traces of sulfur, phosphorous and other impurities before casting.

The principal energy consuming operations in copper smelting are in drying, smelting and converting. The typical copper concentrate feed will contain from eight to twelve percent moisture. Drying, normally accomplished in rotary devices, will reduce that moisture to less than one percent, suitable for direct feeding to the smelting unit or for pelletizing. Although present practice frequently utilizes natural gas as a dryer fuel, a systematic shift is underway for both existing and new installations toward use of fuel oil or coal for that purpose.

Smelting requires a considerable quantity of extraneous energy; that need may be filled with natural gas, oil, coal or electric power. In general, smelting of dried concentrate will require from two to seven million Btu's per ton of concentrate.

Converting of copper matte necessitates extensive blowing of air (oxidation) through the molten material. The principal energy requirement is either electrical or steam for air blower operation.

Power failures are not of major importance to copper smelting operations provided that reasonable alternate emergency systems are provided. During medium to long-term outages, the converting vessels are drained since no practical means are provided for melting solid material resulting from cooling. Normally, during long-term outages, the smelting vessel or furnace will also be drained. Where slag-resistance electric smelting is used, the smelting vessel is not drained. Other than cycling effects on refractories, and additional energy use, power outages are not highly deleterious to the copper operations.

Process modifications in recently constructed (and probably forthcoming) smelters have been directed toward cleaner off-gases and increased energy efficiency. As sulfide concentrate contains a large quantity of latent energy, the modifications have led to process autogeniety. Where electric smelting has been adopted; it is because of operational flexibility and comparatively lower power cost, viz a viz the other energy costs.

D. At this time, national industry capacity for smelting of copper materials to semi-refined or anode copper is about 1.3 millions annual tons. Of that installed capacity, approximately 80 percent is presently being used because of the material existing in inventories.

Process changes underway and anticipated to meet both environmental and energy-cost constraints probably include a shift to process thermal autogeniety (like flash or Noranda smelting), to more and more efficient thermal recovery from off-gas streams, to oil and coal fuel use and to electric smelting because of its smaller and cleaner off-gas. Hydrometallurgical process are in development but environmental and energy advantages are not apparent while recovery problems continue to exist.

Various sources have been examined regarding use-growth for copper between 1985 and 2000. Predictably, a major growth area will be in solar, heat-recovery applications. Estimates indicated a national growth pattern during those years of from three to about five percent per annum.

E. Beyond continued movement to utilization of the electric, Noranda and flash smelting processes, no other likely substantial shift is anticipated. Other process variations are available but their advantages are relatively minor and uncertainties persist. However, it is expected that upwards of 90 percent of all national copper smelting will embody one of those three processes by the year 2000.

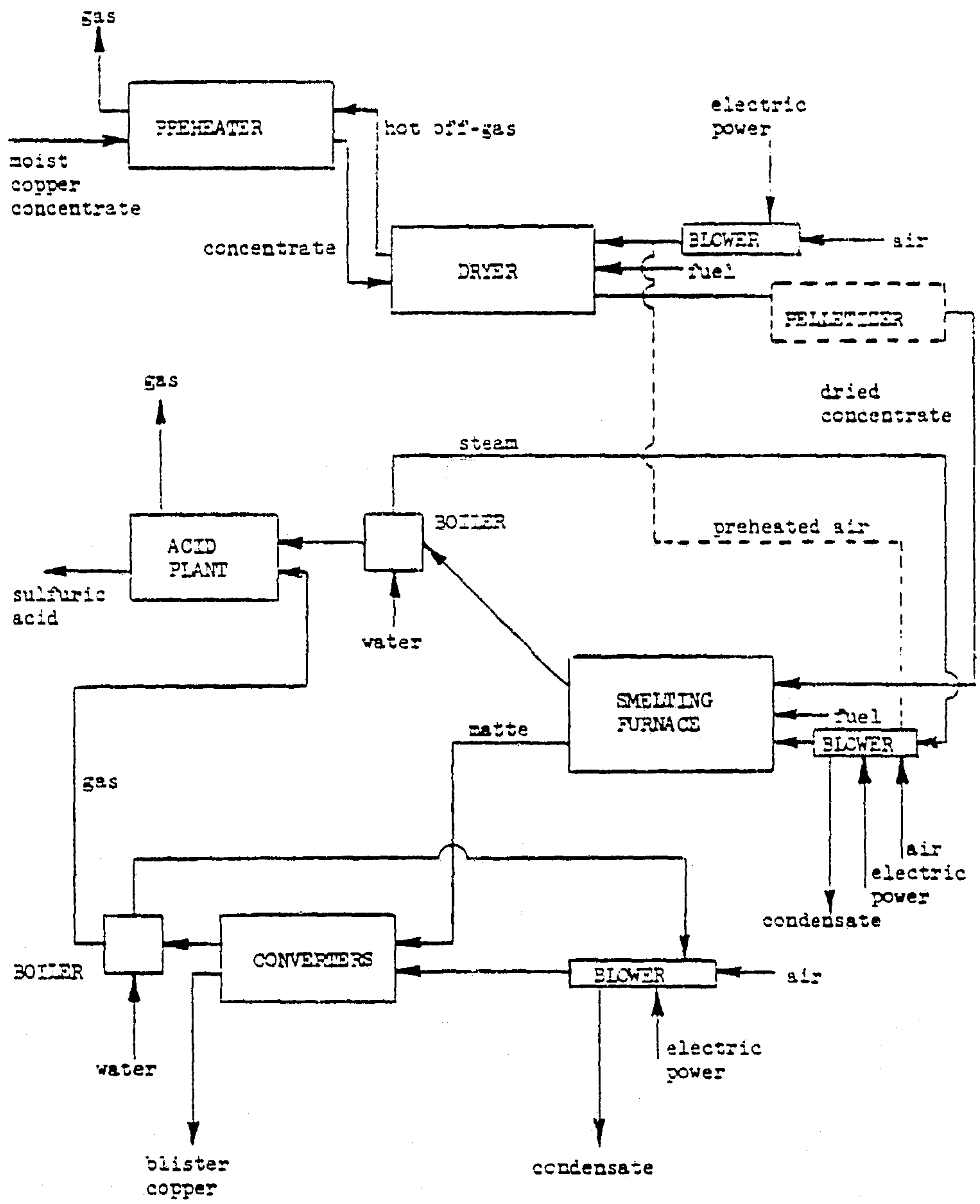
F. Using 2 million tons of copper national production in a base year in the 1985 to 2000 period, total national energy consumed will approximate 36×10^{12} Btu per year. Where Noranda and flash processing is used (about 80 percent of production), roughly 82 percent of the energy will be supplied by carbonaceous fuel. For electric smelting, 20 percent of the production, about 95 percent of the energy will be supplied as electric power.

G. The average energy consumption per ton of copper, utilizing the three major new processes would be 18.5 million Btu's or about 5,500 kwh. Currently, power cost (electric) in the copper producing areas is about $0.02 per kwh.

H. Present plants operating nationally in the copper smelting industry have a capacity ranging from 35,000 to 280,000 short tons per year. A typical U.S. plant operating presently will produce 84,000 short tons per year. During the 1935 to 2000 year period, a typical plant will produce 140,000 short tons per year.

BY .... DATE .... SUBJECT .... SHEET NO. .... OF ....
CHKD. BY .... DATE .... JOB NO. ....

CTAS - COPPER SMELTER



CTAS Plant Data Sheet

A. Plant Name/Size: Copper Smelter; 405,000 short tons per year concentrate
72,500 short tons per year

B. Products:

Product	lb/yr, etc.
Anode Copper	72,500 short tons per year
Sulfuric Acid	310,000 short tons per year
Precious Metals, Gold, etc.	indeterminate

C. Plant Kilowatt Requirements: Average 10,100 kW; Peak 11,400 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
40,000	@	140-150	90	240° F.
	@			
	@			

E. Other Heat to Process (Describe):

83,000 M Btu/hr. for smelting.
28,000 M Btu/hr. for drying.

F. Plant Hours of Operation at Average Conditions: 7,620 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
150-2,000	2,500	1,200 rpm	1,200-1,800	Elect. Motors and Steam Turbines

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
600 M	2,300° F.	Off gas from smelter reactor and converters.

CTAS Plant Data Sheet

Plant Name/Size: Copper Smelter; 405,000 short tons per year concentrate
72,500 short tons per year

J. Fuels: Primary Fuel Oil / 83 mil. Btu/hr (HHV)
Secondary Fuel Oil or Coal / 28 mil. Btu/hr (HHV)
By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Copper Smelter, 160,000 short tons per year

B. Products:

Product	lb/yr, etc.
Fire refined copper	160,000 stpy
Sulfuric Acid	650,000 stpy
Precious metals, gold etc.	indeterminate

C. Plant Kilowatt Requirements: Average 25,800 kW; Peak 28,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
None	@			
	@			
	@			

E. Other Heat to Process (Describe):

249,000 M Btu/hr for smelting
58,000 M Btu/hr for concentrate drying

F. Plant Hours of Operation at Average Conditions: 8,400 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
50 to 2,000	100 to 2,500	1,200	1,200-1,800	Elect. motors

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,400 M	2,250° F	Off gas from flash smelting furnace and converters.

CTAS Plant Data Sheet

Plant Name/Size: Copper Smelter, 160,000 short tons per year

J. Fuels:
   Primary Fuel Fuel Oil / 249 mil. Btu/hr (HHV)
   Secondary Fuel Oil or Coal / 58 mil. Btu/hr (HHV)
   By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Copper Smelter, 175,000 short tons per year

B. Products:

Product	lb/yr, etc.
Fire refined (anode) copper	175,000 stpy
Sulfuric Acid	710,000 stpy
Precious metals, gold silver, platinum group	indeterminate

C. Plant Kilowatt Requirements: Average 28,500 kW; Peak 31,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
None	@	,	,	
	@	,	,	
	@	,	,	

E. Other Heat to Process (Describe):

273,000 M Btu/hr for smelting
64,000 M Btu/hr for concencrate feed drying

F. Plant Hours of Operation at Average Conditions: 8,400 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
50 to 2,000	100 to 2,500	1,200 RPM	same	Elect. motor

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,560 M	2,250° F	Off gas from the flash smelting furnace and converters

CTAS Plant Data Sheet

Plant Name/Size: Copper Smelter, 175,000 short tons per year

J. Fuels: Primary Fuel Fuel Oil / 273 mil. Btu/hr (HHV)

Secondary Fuel Fuel Oil or Coal / 64 mil. Btu/hr (HHV)

By-product Fuel None / mil. Btu/hr (HHV)

K. Fuels Discussion: Coal at an equivalent Btu imput could be substituted for the primary fuel; however, significant additional capital would be required in that event for cleaning of the smelting off gases.

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Copper Smelter, 140,000 short tons per year
700,000 short tons/year concentrate

B. Products:

Product	lb/yr, etc.
Fire refined copper	140,000 stpy
Sulfuric Acid	570,000 stpy
Precious metals, gold etc.	indeterminate

C. Plant Kilowatt Requirements: Average 24,800 kW; Peak 27,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
None	@	,	,	
	@	,	,	
	@	,	,	

E. Other Heat to Process (Describe):

218,000 M Btu/hr for smelting -
51,000 M Btu/hr for concentrate drying -

F. Plant Hours of Operation at Average Conditions: 8,400 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
50 to 1,750	7,000	1,200 rpm	1,200 to 1,300 rpm	elect. motor

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,150 M	2,250 °F	Off gas from flash furnace and converters.

CTAS Plant Data Sheet

Plant Name/Size: Copper Smelter; 140,000 short tons per year
700,000 short tons per year concentrate

J. Fuels: Primary Fuel Oil / 218 mil. Btu/hr (HHV)

Secondary Fuel Oil or Coal / 51 mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Copper Smelter, 163,300 short tons per year; 960,600 short tons per year concentrate

B. Products:

Product	lb/yr, etc.
Anode Copper	163,300 short tons per year
Sulfuric acid	780,000 short tons per year
Precious metals, i.e., gold	indeterminate

C. Plant Kilowatt Requirements: Average 18,500 kW; Peak 22,000 kW

D. Steam Requirements (Process & Heating):

	lb/hr	@	psig,	Returns %,	Temp. of Returns
*	60,000	@	150	90	240-260° F.
		@			
		@			

* Intermittent use during blower startup.

E. Other Heat to Process (Describe):

187,000 M Btu/hr. for smelting.
62,500 M Btu/hr. for conc. drying.

F. Plant Hours of Operation at Average Conditions: 7,620 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
250-3,000	3,000	1,200	1,200-1,800	Elect. Motor and Steam Turbine

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,520 M	2,300 ° F.	Off gas from smelting reactor and converters.

CTAS Plant Data Sheet

Plant Name/Size: Copper Smelter; 163,300 short tons per year
960,600 short tons per year concentrate

J. Fuels: Primary Fuel Oil / 187 mil. Btu/hr (HHV)

Secondary Fuel Oil or Coal / 62.5 mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

CTAS Plant Data Sheet

A. Plant Name/Size: Copper Smelter: 677,000 short tons per year concentrate
115,000 short tons per year

B. Products:

Product	lb/yr, etc.
Copper (anode)	115,000 Stpy
Sulfuric acid	550,000 Stpy
Precious metals (gold, etc.)	indeterminate

C. Plant Kilowatt Requirements: Average 16,000 kW; Peak 18,000 kW

D. Steam Requirements (Process & Heating):

lb/hr	@	psig,	Returns %,	Temp. of Returns
* 60,000	@	150	90	240-260° F.
	@			
	@			

* Intermittent during furnace startup, by fuel fired boiler.

E. Other Heat to Process (Describe):

132,000 M Btu/hr. for smelting.
44,000 M Btu/hr. for concentrate drying.

F. Plant Hours of Operation at Average Conditions: 7,620 hr/yr

G. Large Horsepower Loads:

Normal hp	Peak hp	Speed	Speed Range	Probable Driver
250-2,500	2,500	1,200	1,200-1,800	Elect Motor and Steam Turbine

H. Operational Considerations:

I. Waste Heat Streams:

lb/hr	Temp.	Description
1,080 M	2,300	Offgas from smelting reactor and converters.

CTAS Plant Data Sheet

Plant Name/Size: Copper Smelter; 677,000 short tons per year concentrate 115,000 short tons per year

J. Fuels: Primary Fuel Oil / 132 mil. Btu/hr (HHV)

Secondary Fuel Oil or Coal / 44 mil. Btu/hr (HHV)

By-product Fuel / mil. Btu/hr (HHV)

K. Fuels Discussion:

L. Applications:

No. of Plants in Years 1985-2000	Where	Cogeneration Potential

M. Application Discussion:

N. Preferred Economic Criteria:

O. Economic Discussion:

P. Duty Cycle and Maintenance Philosophy:

Q. Attach kilowatt, steam or waste stream load curves where appropriate.
Use additional sheets for discussion where required.

RATIONALE FOR DROPPING OUT ZINC AND LEAD
AS CANDIDATES FOR COGENERATION

9.8 Zinc SIC 3333

Zinc is not a likely candidate for cogeneration since the older blast furnace technology is being phased out.

Refining of zinc ores is done by the electrolytic process or by distillation in retorts, electrothermic, or blast furnaces. Over the last ten years the electrolytic process has gradually replaced most retort smelters since it cuts operating costs, improves recovery rates, and upgrades zinc quality.

Due to rising costs of production materials, power, labor and equipment, plus a low market price for zinc metal, the zinc refining process has evolved to a fairly energy efficient arrangement. As such, there is little waste heat that is not reused, there are few possibilities for cogeneration.

Based on the current pricing structure of zinc metal, it seems like there will be only moderate growth in U.S. zinc production capacity.

This, coupled with the relatively energy efficient processes employed today, indicate few, if any, mutual advantages to combining a zinc refinery and a power plant on the same site.

9.9 Lead SIC 3332

Lead production through the blast furnace step and the use of waste heat boilers was a good candidate for cogeneration in the past.

Also, in terms of quantity consumed, lead ranks behind aluminum, copper, and zinc. At present about 53% of the lead used in the U.S. is for batteries. Anti-knock compounds comprise the second largest use (15%) followed by ordinance and a host of other applications.

The use of lead sheet and lead pipe has declined in the U.S. because of the substitution of aluminum and plastic. Chemical application in paints, enamels, and in gasoline has come under increasing criticism because of potential health hazards.

Secondary lead producers have peculiar new problems; not only must they also conform to pollution emission standards, but they also find the technical problems of reclaiming lead are increasing.

5.6 APPENDIX B - SUMMARY OF INDUSTRIAL PROCESS ENERGY CONSUMPTION PROJECTIONS

A. SIC-20 Food

SIC 2011 (1900 BTU Fossil/lb)

Year	Fossile & Elec. National Energy (10^{12} Btu/yr)	National Cap. (10^{6} lb/yr)	Cap.
1978	71	35,000	70%
1985	96	-	-
2000	168	40-50,000	80%

SIC 2026

Year	Fossile & Elec. National Energy (10^{12} Btu/yr)	National Cap. (10^{6} lb/yr)	Cap.
1978	71	60-70,000	80%
1985	80	-	-
2000	101	80-90,000	80%

SIC 2046* (3300 BTU Fossil/lb)

Year	Fossile & Elec. National Energy (10^{12} Btu/yr)	National Cap. (10^{6} lb/yr)	Cap.
1978	104	31,000	70%
1985	141	-	-
2000	159	71,000	80%

*This industry now converted to lbm product produced not corn processed. Also plant capacity changed to 2.6×10^{9} lbm/yr.

SIC 2063

Year	Fossile & Elec. National Energy (10^{12} Btu/yr)	National Cap. (10^{6} lb/yr)	Cap.
1978	100	18,000	70%
1985	118	-	-
2000	162	30,000	80%

SIC 2082

Year	Fossile & Elec. National Energy (10^{12} Btu/yr)	National Cap. (10^{6} lb/yr)	Cap.
1978	75	50-60,000	70%
1985	120	-	-
2000	190	90-110,000	80%

The BTU energy use per pound of product are within ± 20% for the individual 4-digit SIC. It is a function of many variables. Additional information for the food industry is supplied below:

SIC	Ratio Generated elec./purch. elec.	Ratio Fossil purch./elec. purch.
2011	-	4.4
2026	-	2.9
2046	.56	17.1
2063	1.72	83.3
2082	.09	5.7

B. SIC-22 Textiles

SIC-2260

Year	National Energy (10^{12} Btu/yr)	National Cap. (10^6 units/yr)	% Cap.
1978	75	10,000 yd	∿ 80%
1985	75	-	-
2000	75	10,000 yd	∿ 80%

C. SIC-24 Lumber and Wood

SIC-2421

1978	237	40,000 bd ft	75%
1985	300	-	-
2000	400	80,000 bd ft	80%

SIC-2436

1978	100	20,000 sq ft	80%
1985	150	-	-
2000	275	74,000 sq ft	85%

SIC-2492

1978	32	3,400 sq ft	90%
1985	100	-	-
2000	172	24,000 sq ft	90%

D. SIC-26 Paper, Pulp

	National Energy (10^{12} Btu/yr)	National Cap. (10^6 tons/yr)	% Cap.

SIC 2621-2

1978	416	14	90%
1985	454	-	-
2000	784	25	95%

SIC 2621-4

1978	405	18	90%
1985	441	-	-
2000	950	40	95%

SIC 2621-6

1978	63	4.4	90%
1985	69	-	-
2000	128	8.4	95%

SIC 2621-7

1978	102	5.4	90%
1985	110	-	-
2000	205	10.3	95%

SIC 2621-8

1978	176	14	90%
1985	191	-	-
2000	419	31.5	95%

The total energy values for SIC-26 were based primarily on the following check points (1) The Btu/lb of product which was provided in the text, (2) The total national energy as indicated in the Department of Commerce Census, (3) and the national installed capacity as indicated in the GE text. The total energy indicated in the text appeared to be a factor of 2 to 3 greater than census numbers and numbers based on installed capacity and Btu/lb. The following information is provided.

SIC	10^6 Btu/lb
2621-2	33
2621-4	25
2621-6	16
2621-7	21
2621-8	14

E. SIC-28 Chemicals

Year	National Energy (10^{12} Btu/yr)	National Cap. (10^{6} tons/yr)	% Cap.
		SIC 2812	
1978	180	12.5	90-95%
1985	240	-	-
2000	300	22.5	90-95%
		SIC 2813	
1978	22	16	90-95%
1985	33	-	-
2000	66	48	90-95%
		SIC 2819* 1 and (2)	
1978	53 (158)	3(9)	90%
1985	76 (229)	-	-
2000	135 (405)	6.8 (20.3)	-

*These come from 3334-4 & 5. The numbers in ( ) are for 2819-2.

Year	National Energy (10^{12} Btu/yr)	National Cap. (10^{6} tons/yr)	% Cap.
		SIC 2821-2	
1978	50	3	90-95%
1985	110	-	-
2000	160	12	90-95%
		SIC 2821-3	
1978	18	3	90-95%
1985	38	-	-
2000	60	12	-
		SIC 2822	
1978	7	1.5	-
1985	9	-	90-95%
2000	13	3	-
		SIC 2824-1	
1978	30	1.5	-
1985	55	-	90-95%
2000	75	4.5	-

SIC 2823-2

1978	14	1	90-95%
1985	20	-	-
2000	25	2	-

SIC 2865-1

1978	35	3.5	-
1985	65	-	90-95%
2000	90	10	-

SIC 2865-2

1978	6.5	1.5	-
1985	10	-	90-95%
2000	15	4.8	-

SIC 2865-3

1978	20	1.5	-
1985	45	-	90-95%
2000	60	5	-

SIC 2865-4

1978	22	4.5	-
1985	45	-	90-95%
2000	65	13	

SIC 2869-1

1978	0	4.5	-
1985	0 (Use Heat of Reaction)	-	90-95%
2000	0	13	-

SIC 2869-2

1978	300	12	-
1985	750	-	90-95%
2000	1100	48	-

SIC 2869-3

1978	3	1.2	-
1985	6	-	90-95%
2000	11	3	-

		SIC 2869-4	
1978	18	1	-
1985	24	-	90-95%
2000	30	2	-
		SIC 2873	
1978	200	16	-
1985	250	-	90-95%
2000	305	30	-
		SIC-2874	
1978	35	9	-
1985	48	-	90-95%
2000	60	18	
		SIC-2895	
1978	18	2	-
1985	20	-	90-95%
2000	24	3.3	-

The chemical plants generally operate in continuous fashion for long periods of time, such as weeks and months. Based on a 7900 hour a year, there is over a 90% load factor and the chemical industries have been operating close to capacity.

F. SIC - 29 Petroleum

	National Energy (10^{12} Btu/yr)	National Cap. (10^{6} bbl/day)	% Cap.
		SIC 2911-1	
1978	560	3.03	95-100%
1985	580	-	-
2000	630	4.06	
		SIC 2911-2	
1978	850	4.6	-
1985	870	-	95-100%
2000	950	6.1	-

		SIC 2911-3	
1978	1220	6.6	-
1985	1250	-	95-100%
2000	1280	8.8	

When the total energy of SIC 2911 is reviewed, we estimate that it is high but within approximately 20% of the magnitude we would estimate from Census studies and Bureau of Mines Reports.

G. SIC 32 - Stone, Clay, and Glass

	National Energy (10^{12} Btu/yr)	National Cap. (10^6 tons/yr)	% Cap.
		SIC 3211	
1978	55	7.2	-
1985	58	-	80-85%
2000	65	8.5	-
		SIC 3221	
1978	150	16	-
1985	162	-	80-85%
2000	188	20	-
		SIC 3229	
1978	68	6.9	-
1985	76	-	80-85%
2000	93	9.4	-
		SIC 3241-1	
1978	150	30	-
1985	255	-	90%
2000	270	54	-
		SIC 3241-2	
1978	75	10	-
1985	85	-	90%
2000	90	18	-
		SIC 3241-3	
1978	375	50	-
1985	425	-	90%
2000	450	90	-

		SIC 3241-4	
1978	75	10	-
1985	85	-	90%
2000	90	18	-

Because of the nature of the industry, the Btu/ton will decrease toward the year 2000.

H. SIC 33- Primary Metals

	National Energy (10^{12} Btu/yr)	National Cap. (10^6 tons/yr)	% Cap.
		SIC 3312-1	
1978	560	22	80%
1985	952	-	-
2000	1666	67	90%
		SIC 3312-2	
1978	3080	123	80%
1985	5200	-	-
2000	9200	365	90%
		SIC 3312-3	
1978	360	14	80%
1985	612	-	-
2000	1070	43	90%
		SIC 3331-1	
1978	4.6	.25	80%
1985	5.8	-	-
2000	9.3	.52	90%
		SIC 3331-2	
1978	6.1	.34	80%
1985	7.8	-	-
2000	12.4	.69	90%
		SIC 3331-3	
1978	4.6	.25	80%
1985	5.8	-	-
2000	9.3	.52	90%

		SIC 3331-4	
1978	12.2	.67	80%
1985	15.5	-	-
2000	24.8	1.4	90%
		SIC 3331-5	
1978	30.4	1.7	80%
1985	38.8	-	-
2000	62	3.4	90%
		SIC 3331-6	
1978	18.2	1.0	80%
1985	23.3	-	-
2000	37.2	2.1	90%
		SIC 3334-1	
1978	31.8	.53	95%
1985	49.2	-	-
2000	86.4	1.44	95%
		SIC 3334-2	
1978	127	2.1	-
1985	197	-	95%
2000	346	5.8	-
		SIC 3334-3	
1978	159	2.7	-
1985	246	-	95%
2000	432	7.2	-

The values for SIC 33 are high by approximately 50% based upon review of other sources.